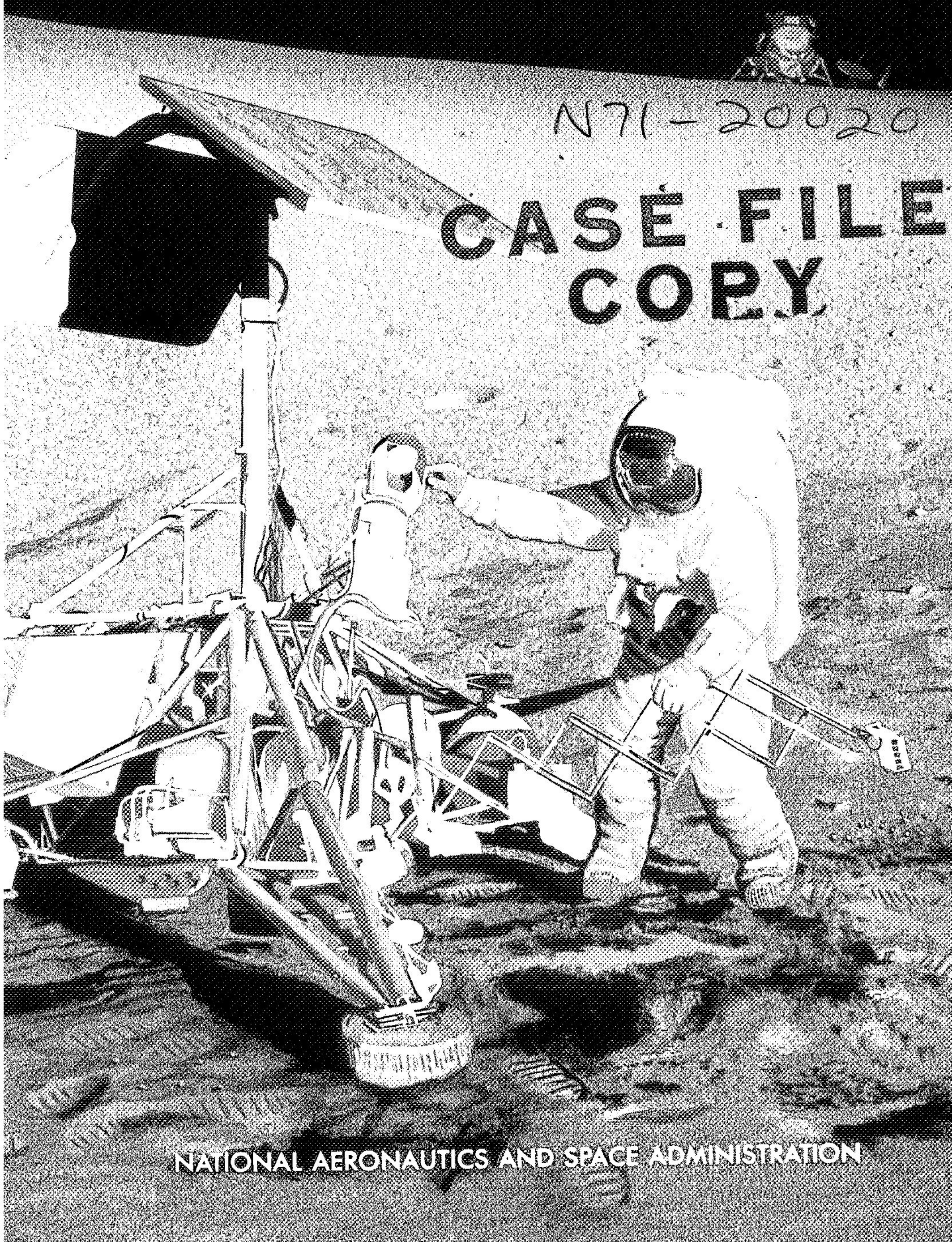
22ND SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1969



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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TO THE CONGRESS OF THE UNITED STATES:

I transmit herewith the Twenty-Second Semiannual Report of the National Aeronautics and Space Administration.

This Report covers the six month period ending December 31, 1969.

Richard Nixon

The White House,

Twenty-second SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1969

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

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THE PRESIDENT October 2, 1970.
The White House

DEAR MR. PRESIDENT:

As required by law, I have the honor to submit this Twenty-Second Semiannual Report of the National Aeronautics and Space Administration for transmittal to Congress. The report covers the period July 1 through December 31, 1969.

The period was highlighted by the Apollo 11 manned lunar landing. On July 20, Astronauts Neil A. Armstrong and Edward E. Aldrin, Jr. landed on the Moon, explored its surface, gathered samples, and then rejoined Astronaut Michael Collins in the command module for a safe return to Earth. Their feat, reported in direct television transmissions, thrilled millions of viewers all over the world. Again, on November 19, the Apollo 12 astronaut team—Charles Conrad, Jr. and Alan L. Bean—landed on the Moon and carried out an extensive exploration of its surface. The two successful Moon missions fulfilled the national goal of a manned lunar landing and safe return within the decade of the sixties and convincingly demonstrated the technological competence of the Apollo program. In addition, these flights showed the value of the space program as a unifying force in international relations, for interest in the Moon landings and in the astronauts transcended national boundaries. This Nation, in turn, took the view that the achievement was a triumph for all mankind even though the deed itself was performed by American astronauts.

Having thus achieved the goal we set for ourselves in the decade just ended, we can now turn our attention to new accomplishments in a continuing effort to expand knowledge and extend our technical ability for the benefit of all the people of the Earth.

Respectfully yours,

GEORGE M. LOW,
Acting Administrator.

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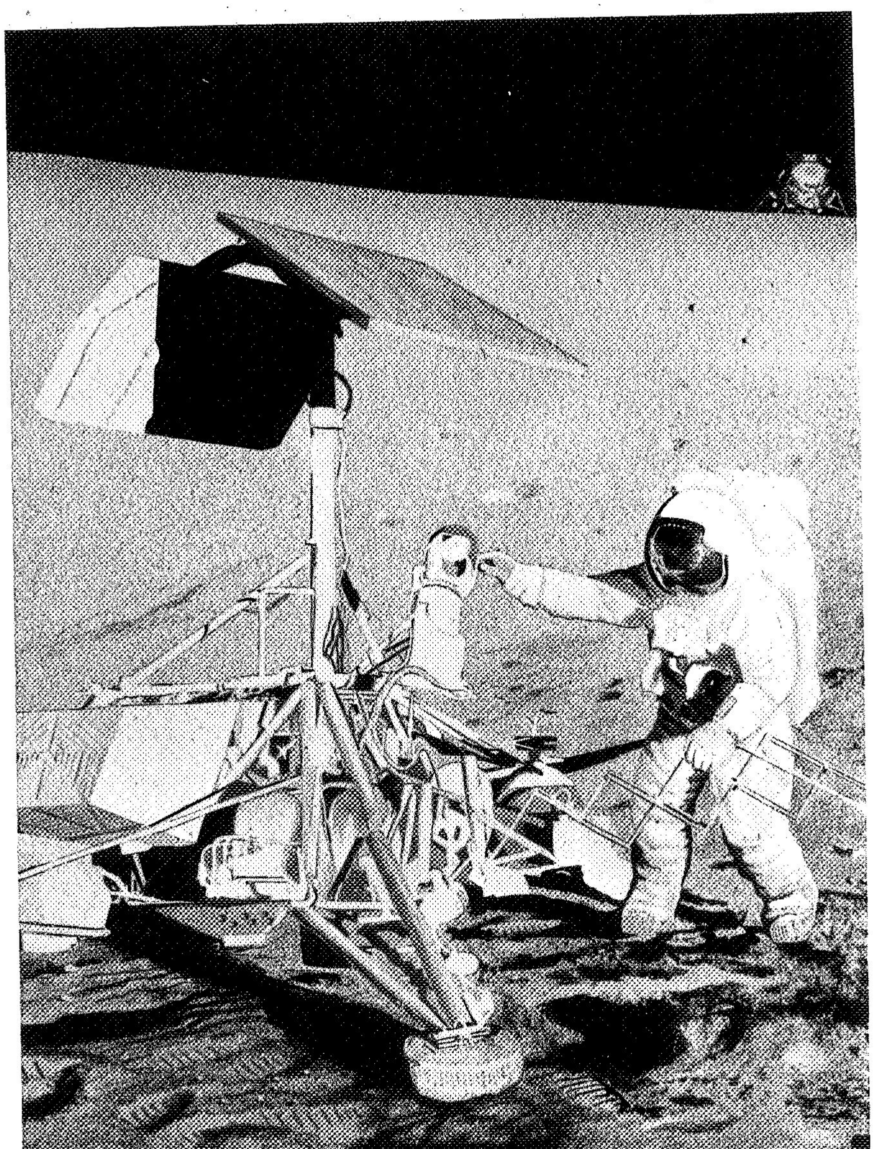
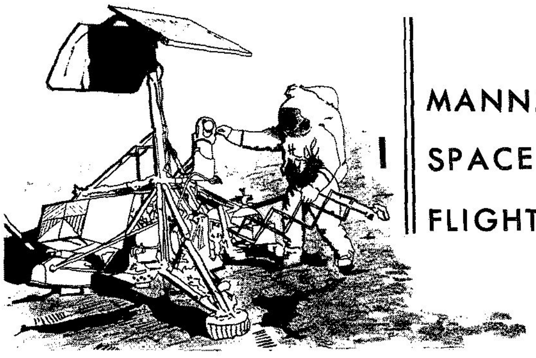




1 MANNED SPACE FLIGHT

During this period, the Nation achieved its manned space flight objective of a lunar landing within the sixties when the Apollo 11 crew set foot on the moon's surface in July. This flight, and subsequently Apollo 12, demonstrated the ability of man to live, work, and conduct detailed scientific explorations on the moon.

Progress was also made in other areas of activity. Development of the Lunar Roving Vehicle, which will enable the astronauts to approximately double their significant scientific activity on future lunar missions, was begun in October. In addition, a major change occurred in the Apollo Applications Program (since renamed Skylab) when NASA decided to replace the "wet workshop" with a "dry workshop." (p. 20) The reconfiguration of the Saturn workshop significantly increases the probability of total mission success.

Major space station activity centered on obtaining the technical and managerial information required for a single approach to a station concept to be selected from the alternate approaches available. In the Space Shuttle Program, the important decision was made that all major systems would be fully reusable. Accordingly, shuttle technology programs were initiated, and major issues and problems were defined.

APOLLO PROGRAM

The initial objective of the Apollo Program was achieved in July, when two Americans landed on the moon, successfully carried out their assigned tasks in the lunar environment, later rejoined their companion astronaut in lunar orbit, and returned safely to Earth. This event was the consummation of the most extensive technological endeavor ever undertaken by mankind,

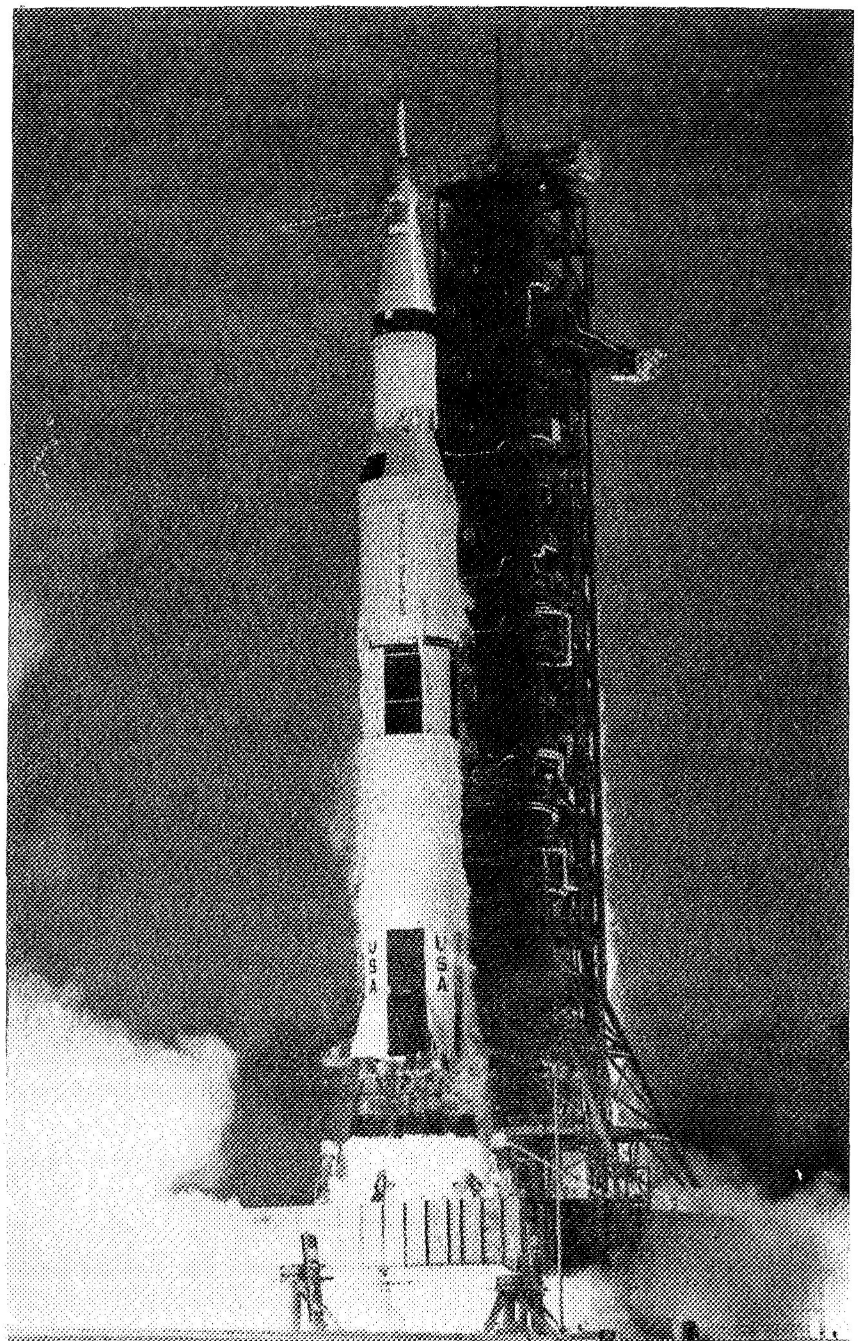


Figure 1–1. Apollo 11 liftoff.

clearly demonstrating this Nation's capability for future manned space exploration.

The successes of manned space flight achieved in Apollo 11 were reaffirmed by the flight of Appollo 12 in November. This flight marked a shift in emphasis from achieving the national goal of landing a man on the moon to conducting scientific explorations of the moon.

Apollo 11 Mission

The Apollo 11 space vehicle was launched from the Kennedy Space Center (KSC) at 9:32 a.m. EDT on July 16. The crew was composed of Commander (CDR) Neil A. Armstrong, Command Module Pilot (CMP) Michael Collins, and Lunar Module Pilot (LMP) Edwin A. Aldrin, Jr. (Fig. 1–1.)

Performing perfectly, the Saturn V booster inserted the third stage and spacecraft into a 100-mile circular earth orbit. One-and-a-half revolutions later, the third stage powered the spacecraft into a translunar trajectory. Three days later, the service propulsion system (SPS) decelerated the spacecraft, placing it in lunar orbit. The spacecraft circled the moon for a day, then the lunar module (LM), with Astronauts Armstrong and Aldrin aboard, separated from the command and service module (CSM) and descended toward the lunar surface.

To this point, the Apollo 11 mission was much the same as Apollo 10. In the descent to the lunar surface, however, there were dramatic differences. During the final approach phase, the crew saw that the LM was headed for the general area of a large, rugged crater, filled with boulders 5 to 10 feet in diameter. Commander Armstrong took manual control and guided the LM to a landing approximately 1,000 feet farther downrange.

As the LM settled on the lunar surface with a slight jolt at 4:18 p.m. on July 20, Armstrong radioed mission control "The *Eagle* has landed." (The LM was named *Eagle,* the CSM, *Columbia.*)

At 10:39 p.m., Armstrong opened the lunar module hatch and started the slow process of descending to the lunar surface. As he descended the ladder, he deployed the Modularized Equipment Stowage Assembly (MESA) containing a television camera which commenced transmitting the event. At 10:56 p.m., he placed his left foot on the moon and radioed "That's one small step for a man, one giant leap for mankind." (Fig. 1–2.)

Approximately 15 minutes later Aldrin emerged from the LM and joined Armstrong on the lunar surface. The astronauts had no

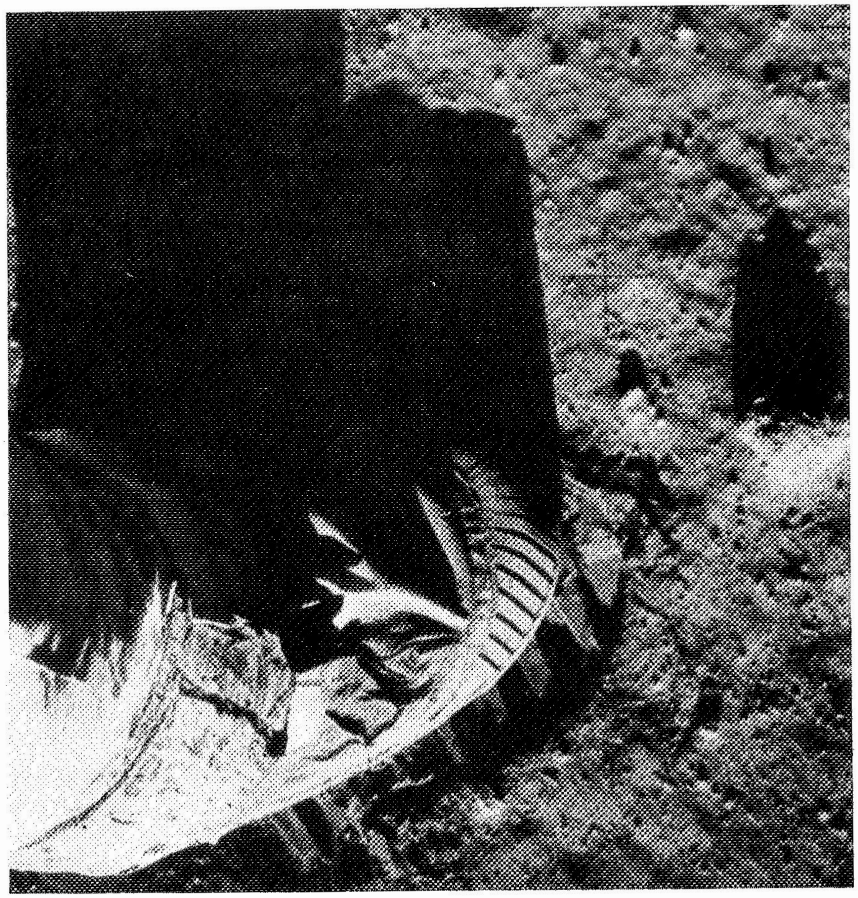


Figure 1–2. Armstrong steps onto the moon.

difficulty in adapting to the lunar gravity, which is one-sixth that of earth.

The landing site area contained numerous boulders approximately 2 feet in diameter, and the predominant colors recorded were various shades of gray. The foot pads of the LM had penetrated the lunar surface to a depth of only 3 to 4 inches, and the Astronauts reported sinking approximately one-eighth of an inch into the fine powdery surface material.

Their activities on the lunar surface consisted of collecting 54 pounds of lunar material, including two core samples from depths of from 6 to 8 inches below the lunar surface, and discretely selected surface samples. Also, they deployed the Early Apollo Scien-

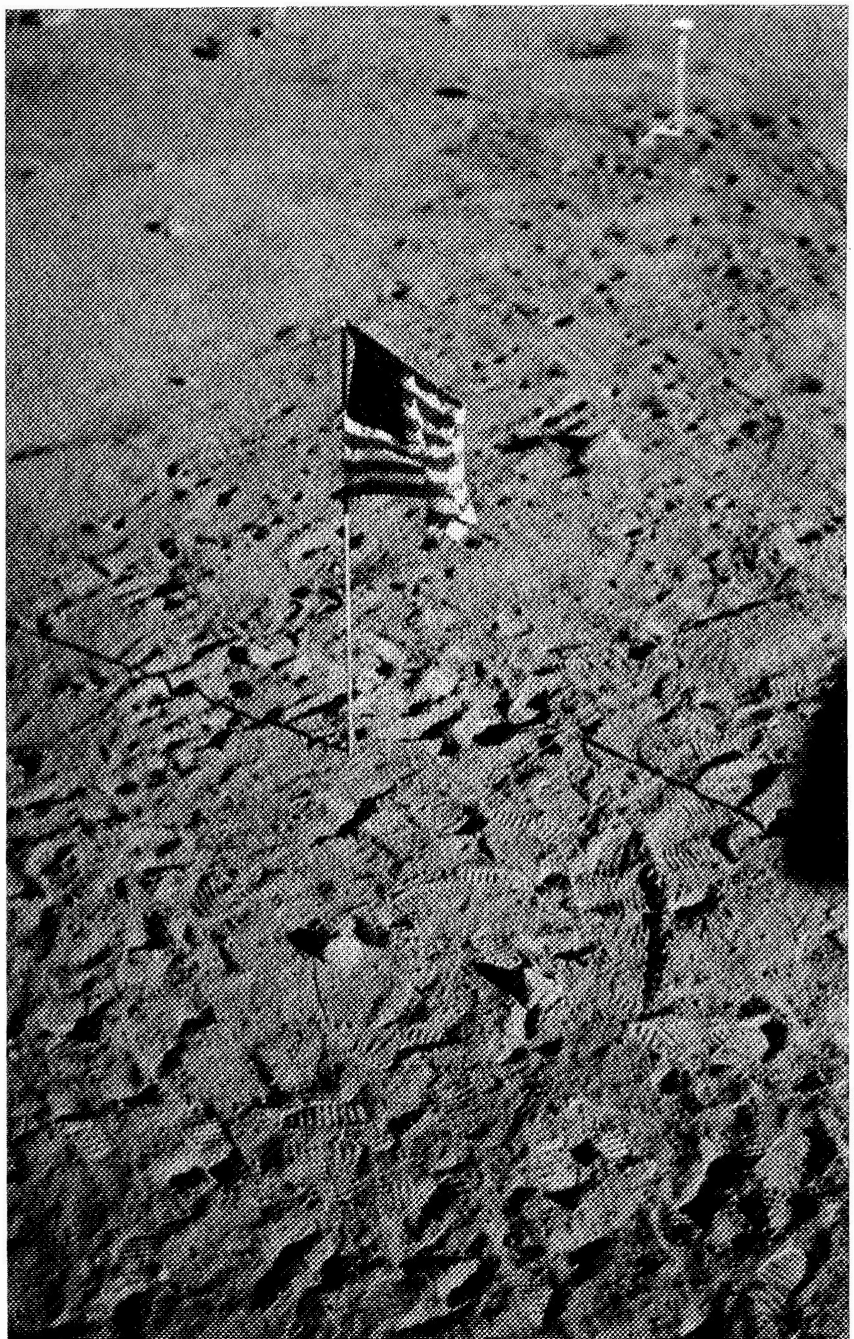


Figure 1–3. The U.S. flag on the moon.

tific Experiment Package (EASEP). This package included a solar cell-powered seismometer designed to measure the seismic activity of the moon, as well as to detect meteoroid impacts, lunar oscillations, and tidal effects. The package also included a Laser Ranging Retroreflector, a passive device consisting of an array of 100 precision reflectors which is being ranged upon by earth–based laser systems. This experiment will make it possible to measure the earth-moon distance much more precisely, the motion of the Moon about its center of gravity, lunar size and orbit, changes in the gravitational constant, and the distance between continents on Earth. The astronauts also deployed an aluminum foil panel to collect solar wind particles.

The astronauts also unveiled a plaque on the LM descent stage, erected an American flag on the lunar surface, and talked directly to President Nixon in the White House through NASA's extensive communication network. (Fig. 1–3.)

Their activities completed, the astronauts returned to the LM, concluding a 2½-hour period on the lunar surface for Armstrong, and about a 2-hour period for Aldrin. Several hours later the astronauts lifted off the lunar surface, rendezvoused with the CSM, and docked with it as planned.

The first visit of man to the moon's surface was concluded successfully on July 24, with splashdown in the Pacific and recovery of the astronauts by the USS *Hornet*. During recovery, extreme precautions were taken against possible contamination. Special biological isolation procedures, designed to protect the earth's biosphere from possible lunar contamination, were employed during the mission and during the after recovery. (Fig. 1–4.)

All elements of the communications system (voice, telemetry, television, and tracking) performed satisfactorily throughout the flight and lunar stay. Flight crew performance was outstanding. All three astronauts remained in excellent health and made continued references to the excellence of the food. Their good spirits and great proficiency (as well as that of the ground crews) were evident throughout the mission and were major factors in its success.

Apollo 12 Mission

The second lunar landing mission, Apollo 12, was launched on schedule from KSC, at 11:22 a.m., e.s.t., November 14. Crew members were CDR Charles Conrad, Jr., CMP Richard F. Gordon, Jr., and LMP Alan L. Bean. Approximately 36 seconds after liftoff, an

Figure 1–4. Astronauts move to quarantine facility.

electrical discharge passed through the spacecraft to the ground, causing an automatic disconnect in the electrical system. The crew acted swiftly, closing the circuit breakers and overload detectors to restore power. Otherwise, all launch vehicle stages performed satisfactorily, inserting the spacecraft and third stage combination into an earth parking orbit of approximately 101 nautical miles. After orbital insertion, the inertial measurement unit platform

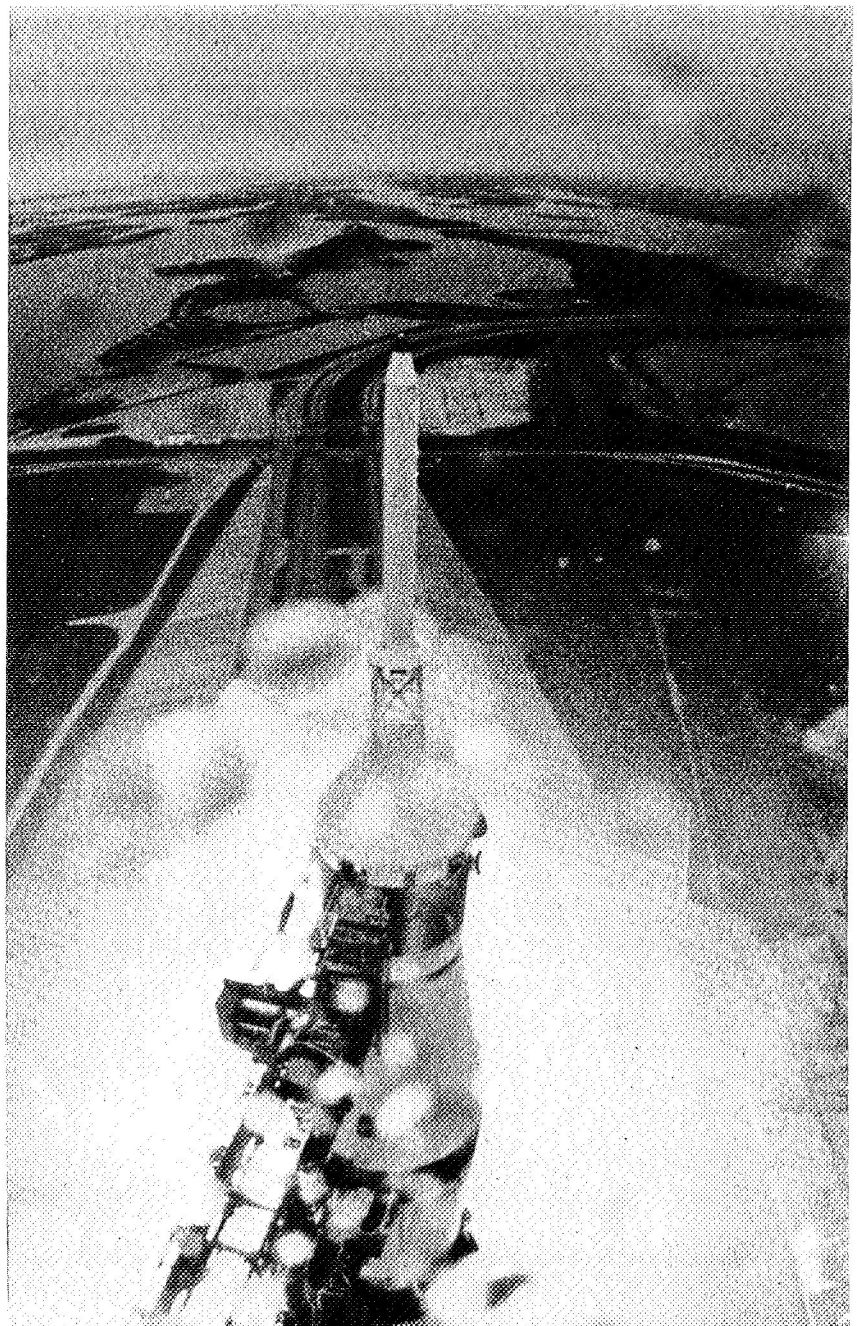


Figure 1–5. Apollo lifts off in rain.

was realigned and special checks were made in the CSM and LM. (Fig. 1–5.)

After one-and-a-half earth orbits, a second firing of the S–IVB stage injected the spacecraft into a translunar trajectory, and the CSM separated, turned around, and docked with the LM. The Apollo 12 trajectory differed significantly from that of previous manned lunar missions. On those, a free return trajectory was flown—that is, one which in an emergency would return the spacecraft to Earth after it circled the Moon with no need to fire the main spacecraft engines. In Apollo 12, however, the astronauts made a mid-course correction which put the spacecraft into a hybrid or non-free return trajectory. The hybrid trajectory for this mission permitted a daylight launch and translunar injection over the Pacific Ocean, conserved fuel, and resulted in an approach to the landing site when the sun was at the desired elevation for best visibility.

The spacecraft went into lunar orbit at 10:47 p.m. e.s.t. on November 17, and CSM/LM undocking took place at 11:16 p.m. e.s.t. on November 18. Certain techniques developed for Apollo 12 to improve landing accuracy proved effective and the LM (*Intrepid*) landed about 600 feet from its target, Surveyor 3. (Fig. 1–6.)

The Apollo 12 mission had several purposes: to develop techniques for a point landing capability; to perform geological inspection, survey, and sampling in a mare area; to deploy and activate an Apollo Lunar Surface Experiments Package (ALSEP); to develop man's capability to work in the lunar environment; and to photograph candidate exploration sites.

The point landing capability was clearly demonstrated. After a period of rest and preparation, Astronauts Conrad and Bean left the LM and began to carry out the tasks related to the scientific objectives of the mission. The first extravehicular activity period started at 6:44 a.m. e.s.t., November 19, when Commander Conrad first touched the lunar surface. About 30 minutes later, he was joined by Bean.

Television transmission was lost shortly after the camera was removed from the bracket in the MESA and, despite repeated efforts, was not regained for the remainder of the EVA. While direct exposure of the camera lens to sunlight was considered the most probable cause of the TV failure, the problem was still being analyzed as the period ended.

After taking a contingency sample and deploying the S-band erectable antenna, the Solar Wind Composition Experiment, and an

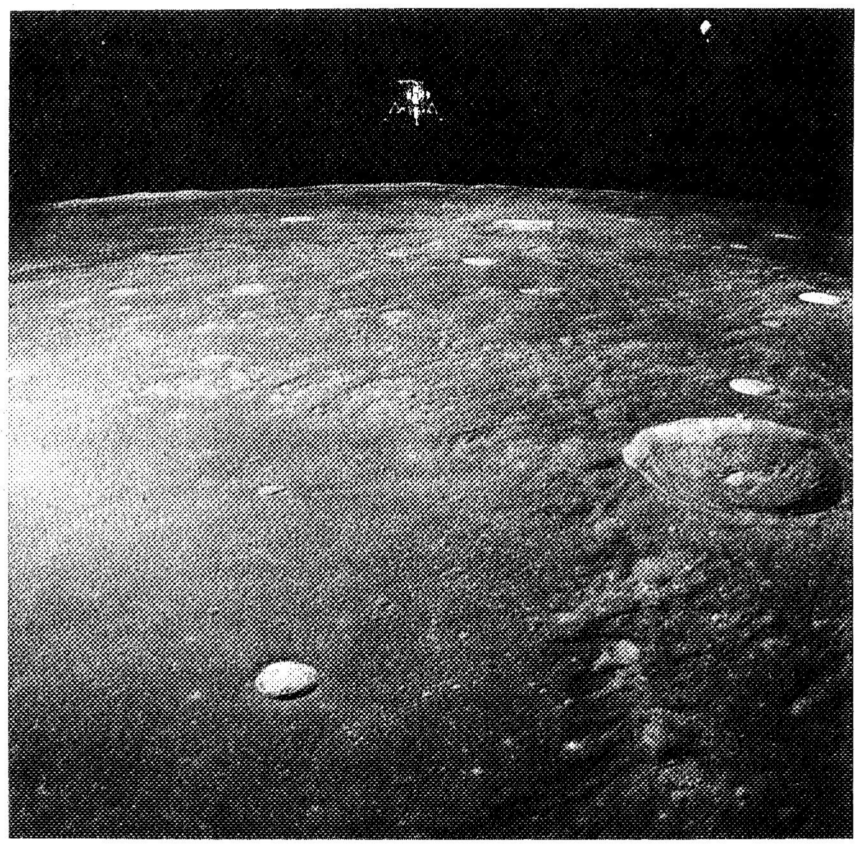


Figure 1–6. *Intrepid* prepares to land on the moon.

American flag, the two astronauts unloaded the ALSEP and deployed it about 600 feet from the LM. The ALSEP, a much more sophisticated array of experiments than that deployed on the Apollo 11 mission, contains its own energy source—a radioisotope thermoelectric generator which supplies nuclear electrical power for the six experiments. The ALSEP experiments are: a passive seismometer to measure seismic activity of the moon; a magnetometer to measure the magnetic field of the moon; a solar wind spectrometer to measure the strength, velocity, and directions of the electrons and protons which emanate from the sun and reach the lunar surface; a suprathermal ion detector to measure the characteristics of positive ions near the lunar surface; a cold cathode ion gage to determine the density of any lunar ambient atmosphere; and a detector to measure the amount of dust accretion on the

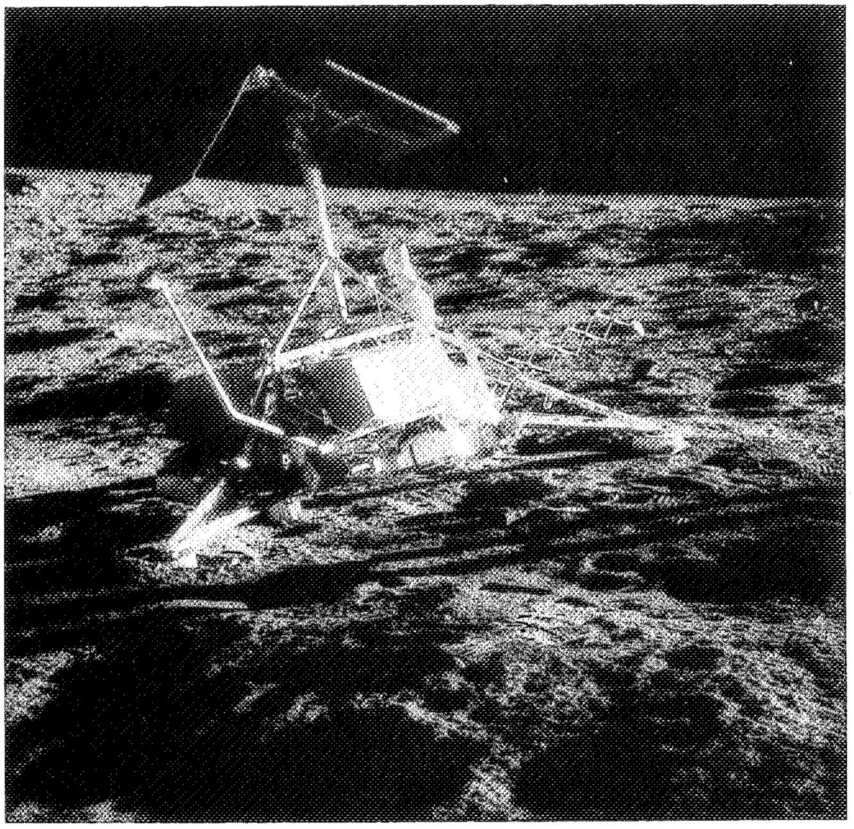


Figure 1–7. Surveyor 3 photographed during second EVA.

ALSEP to provide a measure of the degradation of thermal surfaces. The ALSEP array will remain on the surface to transmit scientific and engineering data to earth for at least a year.

After a first EVA of about 4 hours, the astronauts reentered the Lunar Module, rested for about 5 hours, and discussed with Houston the plans for the second walk.

The second EVA began at 10:55 p.m. e.s.t. November 19 and lasted for 3 hours and 49 minutes. The crew walked to the ALSEP deployment site, to several craters, to Surveyor 3, and back to the LM. They went between 1,500 and 2,000 feet from the LM, covering a total distance of about 6,000 feet. During this EVA, the crew took photographs, gathered samples, and retrieved parts from the Surveyor for later analysis on earth. (Fig. 1–7.)

After the walk, the astronauts retrieved the Solar Wind Compo-

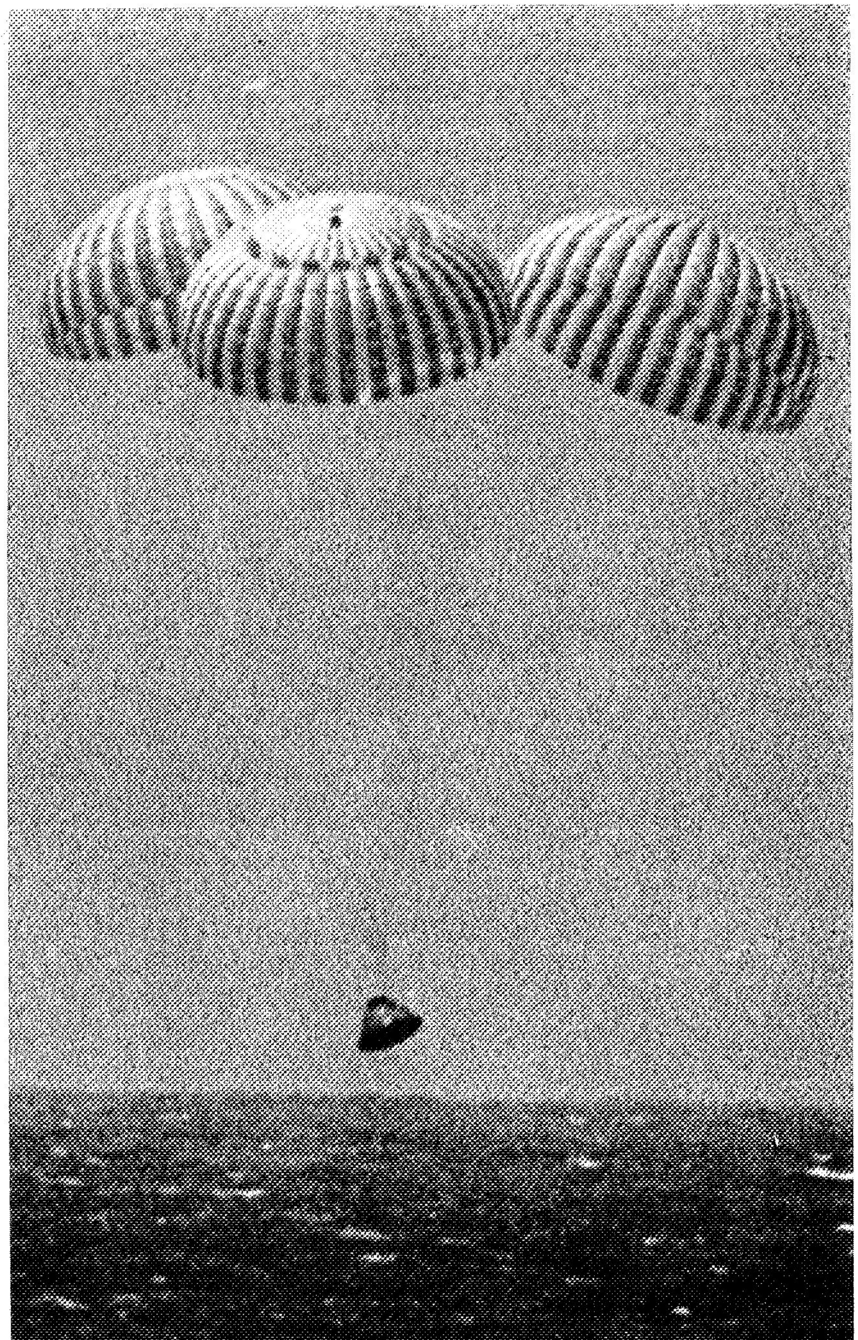


Figure 1–8. Apollo 12 spacecraft nearing splashdown

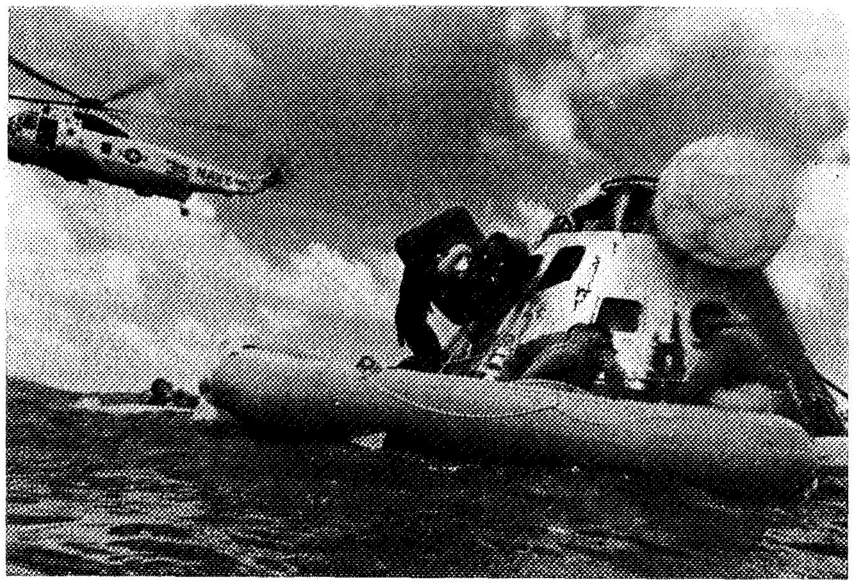


Figure 1–9. Astronaut Bean climbs out of CM.

sition Experiment, reentered the LM, stowed all the collected samples, parts, and equipment in it, and repressurized the cabin. Lunar liftoff occurred at 9:26 a.m., e.s.t., November 20, concluding a total lunar stay of 31 hours, 31 minutes. No difficulty was encountered during rendezvous and docking with the CSM *Yankee Clipper*.

After the two astronauts transferred back to the CM, the LM ascent stage was jettisoned and deliberately impacted on the moon to provide a signal for the seismometer. It landed about 45 miles from the ALSEP at a speed of about 5,000 m.p.h. Scientists were surprised at the length of time (55 minutes) that vibrations continued to be recorded by the instrument after impact. On earth they would have registered for about 2 minutes on an earth-type seismometer. The CSM continued in orbit to achieve the final objective of the mission—obtaining photos of candidate future landing sites, Fra Mauro, Descartes, and Lalande.

The maneuvers for return to earth were all nominal, and the spacecraft splashed down in the Pacific at 3:58 p.m., e.s.t., on November 24. (Fig. 1–8.) The USS *Hornet* again made the recovery, as on the Apollo 11 mission. (Fig. 1–9.)

Post mission analysis indicated that the space vehicle triggered two lightning events soon after liftoff. At 36.5 seconds ground

elapsed time (GET), a cloud to ground discharge via the space vehicle occurred, and at 52 seconds GET a cloud to space vehicle to cloud discharge occurred. Most of the effects of these discharges were temporary and were corrected by the crew. The only permanent damage was to temperature and pressure measuring devices; their functions were performed by alternate means.

Guidance and control functions were excellent on this mission as on previous ones. Three of the four programed mid-course corrections during translunar trajectory were not required and were eliminated. On the earth-return trajectory, one of three planned corrections was eliminated.

Communications were very good throughout the mission except for occasional problems with the High Gain Antenna (HGA) and failure of the television camera after its removal from the MESA early in the first EVA. On several occasions communications with the CSM experienced some degradation because the HGA could not hold lock. Two special HGA tests were conducted during the transearth coast to attempt to resolve the anomaly. Results of these tests identified probable causes which the Agency was still investigating.

Performance of the Apollo 12 astronauts was outstanding throughout the mission in every way. Their fast thinking and alert reaction during the two lightning events quickly corrected the problem and dispelled the anxiety of ground observers.

Astronauts Conrad and Bean provided a detailed and comprehensive commentary on the lunar surface activities. They were initially cautious in their movements but eventually adapted well so that they were able to move about with relative ease and without tiring. Commander Conrad fell once but was able to recover easily from the prone position without assistance. He suggested, however, that a strap be added to facilitate buddy assistance. Both astronauts became somewhat thirsty during the extended EVA's in the lunar surface suits, but they were able to accomplish all lunar surface requirements. For Apollo 13, drinking water will be available to the astronauts during EVA.

Minimum medication was used by the crew, mostly decongestants to relieve stuffiness attributed to lunar dust transferred to the CM by the suits and gear used on the lunar surface. Astronaut Bean used sleeping pills before two of his rest periods following LM ascent stage separation. Skin cream was used by Commander Conrad for relief of a rash caused by his biomedical sensors. The crew was exceptionally enthusiastic during all phases of the mission, especially during EVA and television transmissions.

Apollo 13 Mission Summary

The Apollo 13 mission is scheduled to be launched in April 1970, with the Fra Mauro landing site as its objective. Flight hardware for this mission is to consist of the SA–508 launch vehicle, CSM–109 Command and Service Module, and LM–7 Lunar Module. This is to be the second of four flights planned in the H-series missions which use standard Apollo flight hardware for lunar exploration. The Apollo 13 astronauts are scheduled to be on the lunar surface about 35 hours, including two EVA periods. An ALSEP is to be placed on the Moon to record and transmit the important scientific data to Earth for up to a year.

Production, Development, and Test

Fifteen Saturn V vehicles were procured for the Apollo Program. Seven have been launched and two are scheduled for launch in calendar year 1970. One Saturn V, which is capable of placing 145 tons into low earth orbit or sending 50 tons to the moon, will launch the Apollo Applications Workshop, which has been renamed Skylab, in 1972; it had previously been scheduled for an Apollo lunar mission.

Production of the 15 Saturn V's was nearing completion. Some completed stages are to be placed in storage to await the dates when they must be delivered to KSC to meet the revised Apollo launch schedule. Procurement of additional Saturn V vehicles, beyond the 15 on order, was suspended. However, manufacturing techniques, test and checkout procedures, and associated data are to be preserved to provide the basic capacity for the resumption of Saturn V production.

The Command and Service Modules achieved all major objectives during the Apollo 11 and Apollo 12 missions as they had in Apollo 9 and 10. Only minor discrepancies occurred, presenting no hazard to crew or spacecraft. NASA was planning to modify the CSM to enable Apollo 16 and subsequent flights to support lunar landing missions of up to 16 days from launch to splashdown. Changes are to include an extra oxygen tank and an extra hydrogen tank. Also, configuration changes will make it possible to stow additional consumables, science experiments, and EVA equipment, and more lunar samples.

Other changes will make it possible to carry out scientific experiments while the CSM is in lunar orbit. Additions will include a Scientific Instrument Module (SIM) in one bay of the Service Module, appropriate displays and controls in the Command Module, and

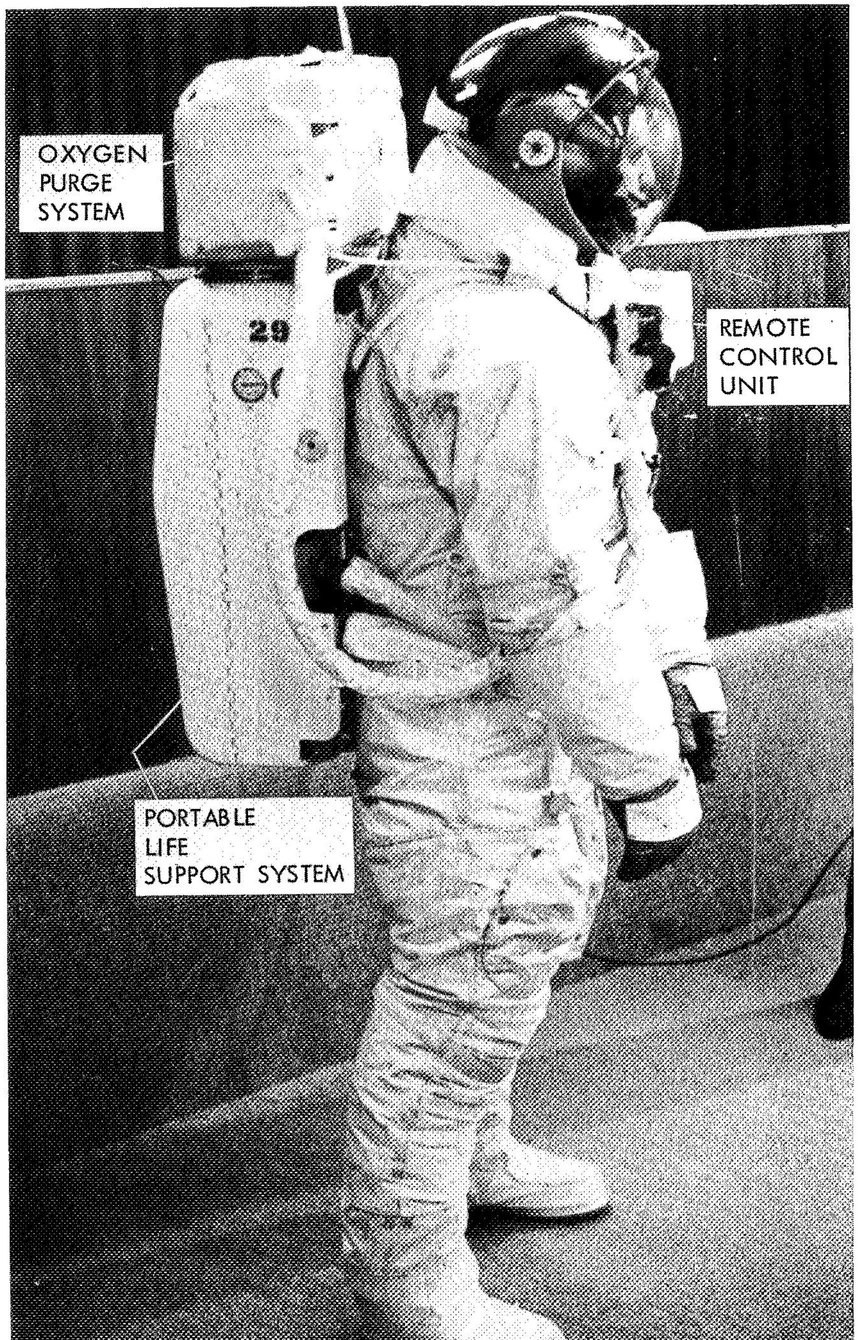


Figure 1–10. The A7L spacesuit.

wiring between the CM and the SM. EVA handrails are being added to the SM to facilitate retrieval of experimental data.

The Lunar Module also demonstrated operational maturity on the two lunar landing missions. However, it, too, will be changed for the extended time missions. Plans are to increase the lunar surface stay time to at least 54 hours and to carry both a Lunar Roving Vehicle (LRV) and an ALSEP.

To make room for the LRV, the LM batteries will be relocated. Additional batteries are also being provided. The LM descent stage propellent tanks are being enlarged to increase their capacity by some 1,200 pounds. This increase can either permit a greater payload or increase maneuver time during landing approach.

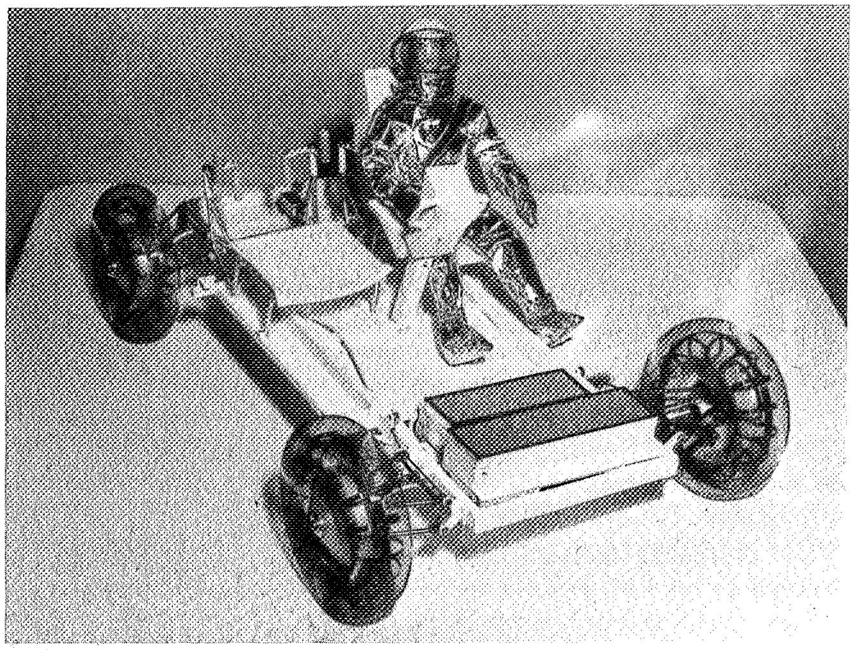
The astronauts will continue to use the A7L model spacesuit with changes to increase mobility and to allow for interface with the modified Portable Life Support System/Secondary Life Support System (PLSS/SLSS) and the LRV. (Fig. 1–10.)

The Apollo 11 model PLSS (the –6PLSS), which can be recharged at the LM, and its backup Oxygen Purge System (OPS) will be used through the Apollo 15 mission. The OPS is an emergency device to support the astronaut for 30 minutes in case of PLSS failure.

A modified PLSS, for use on Apollo 16 and subsequent missions, will have a 4-hour rating at a metabolic rate of 1,600 Btu/hour. (The metabolic rates experienced on the Apollo 11 and 12 missions averaged about 1,000 Btu/hour during EVA.) Increasing the oxygen charge pressure and capacity and enlarging the water tank will give the added capability. This model (designated the –7PLSS) will enable the astronauts to range farther from the landing site because they won't have to interrupt the EVA to visit the LM for recharge. To further support this range increase, an SLSS will replace the OPS, providing improved back-up capability. It will be 20 pounds heavier than the OPS but will occupy the same volume and will provide emergency life support for 1½ to 2 hours in case of PLSS failure.

Cameras and other small orbital experiments are carried in the CM on all missions. On Apollo 16 through 19, a number of orbital experiments will be carried in the Service Module.

NASA approved additional experiments for flight on the CSM in lunar orbit to complement and extend knowledge gained from surface experiments. Examples of such experiments are those which can analyze lunar composition from lunar orbit by detecting radioactivity and measuring spectral reflectivity; radar sounders



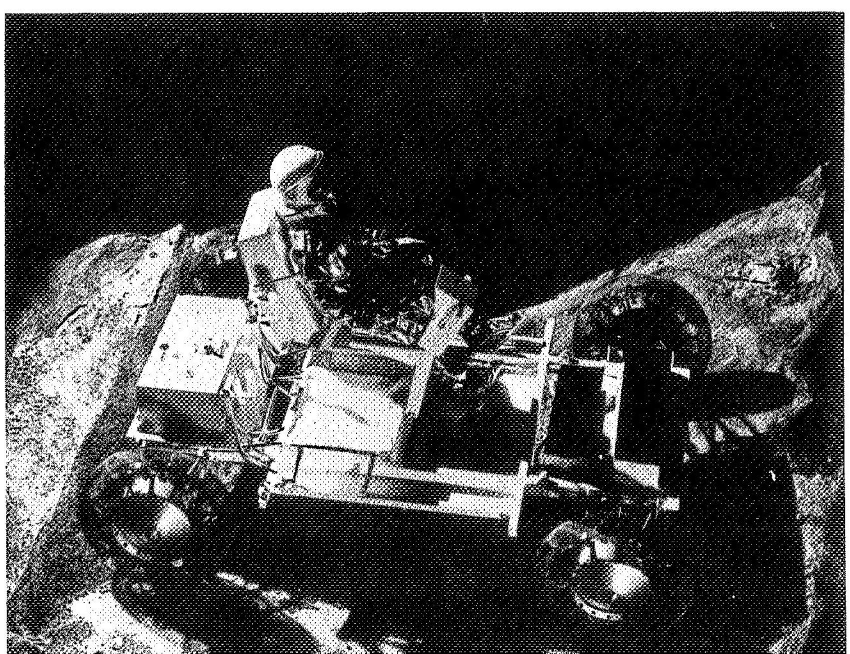


Figure 1–11. Lunar Roving Vehicle models.

which can probe the subsurface of volcanic features examined on the surface by the astronauts; instruments which can measure geochemistry, imagery, geodesy, temperature, subsurface profile, particles and fields, and transient atmosphere.

The Lunar Roving Vehicle, being developed under contract since October 1969, will increase the astronauts' range of travel on the lunar surface. Four LRV's are on order and the first is expected to be carried aboard Apollo 16. A two-man crew will ride the LRV 3 to 5 miles from the LM at speeds up to 10 miles per hour. In addition, the battery-powered LRV will carry up to 170 pounds of equipment and lunar samples. LRV missions will approximately double the significant scientific activity possible on walking missions. (Fig. 1–11.)

Astronauts will first use the LRV to explore what appear to be volcanic domes, plugs, cones, and wrinkle ridges in the Marius Hills region, photographed by Lunar Orbiter 2. The LRV will carry a portable TV communication system, providing a fix at the numerous stops for investigation and sampling, thus making network tracking easier. (The LRV can also be used as a rescue vehicle for a disabled or otherwise imperiled astronaut.)

Lunar Science

The Manned Spacecraft Center (MSC) began distribution of approximately 18 pounds of moon rocks and dust to scientific investigators in September. Lunar samples collected by the Apollo 11 astronauts went to 106 principal investigators in the United States and 36 in eight other countries for analyses in university, industrial, and government laboratories. About 4 kilograms of fine materials and chips and slices of about 30 rocks were distributed for first generation experiments.

Since its return in sealed containers on July 25, all the material was under quarantine in the Lunar Receiving Laboratory (LRL) at MSC where tests on animal and plant life revealed no harmful effects. Release of the samples was approved by the Interagency Committee on Back Contamination, set up to review NASA safeguards against contamination of the Earth by organisms brought back from the Moon.

Preliminary examinations in the LRL revealed two basic rock types: compacted lunar soil, and igneous rocks. The preliminary examination indicated that the rocks have been lying on the lunar surface from 10–150 million years, and that the igneous rocks crystallized 3 to 4 billion years ago.

The Apollo 12 lunar samples are scheduled to be distributed in February 1970.

APOLLO APPLICATIONS

During this reporting period, momentum continued to build in all facets of the Apollo Applications (Skylab) Program. The most important event was the decision to simplify and improve the Saturn Workshop.

Before July 1969, the plan was to employ the spent Saturn 1B second stage as the first Orbital Workshop. The solar astronomy observatory would have been launched by another Saturn 1B, and the two would have been docked. However, tests and systems engineering analyses indicated that flight hardware, launch facility requirements, and space flight operations would be simplified considerably by launching the workshop with a single Saturn V, completely outfitted on earth. The operational simplicity also enhances safety and makes it possible to fly experiments earlier.

The probability of achieving success is improved by the reduced number of launches required, by the greater payload capacity of the Saturn V launch vehicle; by the elimination of the LM ascent stage; and by the ability to check out most systems and experiments on the ground.

Missions

The Apollo Applications Program (Skylab) is designed to conduct scientific investigations in earth orbit, to develop methods of assessing the earth environment from space, and to obtain detailed understanding of man's capability to live and work in space for increasing periods. In flight missions scheduled to begin late in 1972, the AAP will enable NASA to fly the Saturn workshop and obtain much information affecting future manned earth orbital operations.

The principal scientific effort in the program will use a solar astronomy module to make detailed observations of the sun in various parts of the spectrum. An astronomer-astronaut will probably be a member of the crew on at least one of the missions to decide on the conduct of the research program and to direct instruments toward various areas of the sun as conditions change.

Another significant area to be emphasized is applications. This includes activities such as observations of meteorology, communications, material processing, and earth resources. In the last activity, multispectral photography will be used to gather data for ex-

perts studying oceanography, water management, agriculture, forestry, geology, geography, and ecology. The AAP efforts in these areas will add to and complement the knowledge gained from ground-based research and automated space programs.

The third major activity concerns habitability, medical, behavioral, and work effectiveness experiments on missions of increasing duration, probably as long as 8 weeks. A physician-astronaut may be a member of the crew on one of these missions to conduct an intensive program of such experiments. The medical and behavioral studies will focus on the effects of space flight on man and the sequence of these effects through time. The results are expected to add to understanding of healthy human subjects, thus contributing to medical knowledge of value on earth. Biological experiments are also planned to study the effect of zero gravity on living organisms and the effect of alteration of the basic rhythms, such as the sequence of day and night at 24-hour intervals, which influence the life processes.

The first Saturn Workshop mission will consist of two launches —AAP–1 and AAP–2 (redesignated SK–1 and SK–2). In the first launch, a Saturn V will place the unmanned Workshop and Apollo Telescope Mount in an approximate 235 mile orbit inclined 50° to the Equator. This orbit covers most of the heavily populated areas of the earth. The AAP–2 will be launched a day later, using a Saturn 1B vehicle to place the manned Apollo CSM in the same orbit. After the two sections dock the three-man crew will set the Workshop and astronomy module in operation, and carry out an open-ended mission, possibly lasting as long as 28 days.

There will be two Workshop revisits—AAP–3 and AAP–4 (redesignated SK–3 and SK–4). On these missions, Apollo-Saturn 1B vehicles will be launched at 3-month intervals after the first Workshop becomes operational.

Development and Testing

Subsystems and complete assemblies of the Saturn Workshop, Airlock Module, Multiple Docking Adapter and Apollo Telescope Mount were well advanced into the design, development, and ground testing stage. The first flight article, Saturn Workshop I, was being fabricated, and the flight systems were scheduled for delivery to KSC in late 1971. The launch was put off from mid-1972 to the last quarter of that year for budgetary reasons. Hardware for a second Workshop was being procured as a backup to the first mission. (Fig. 1–12.)

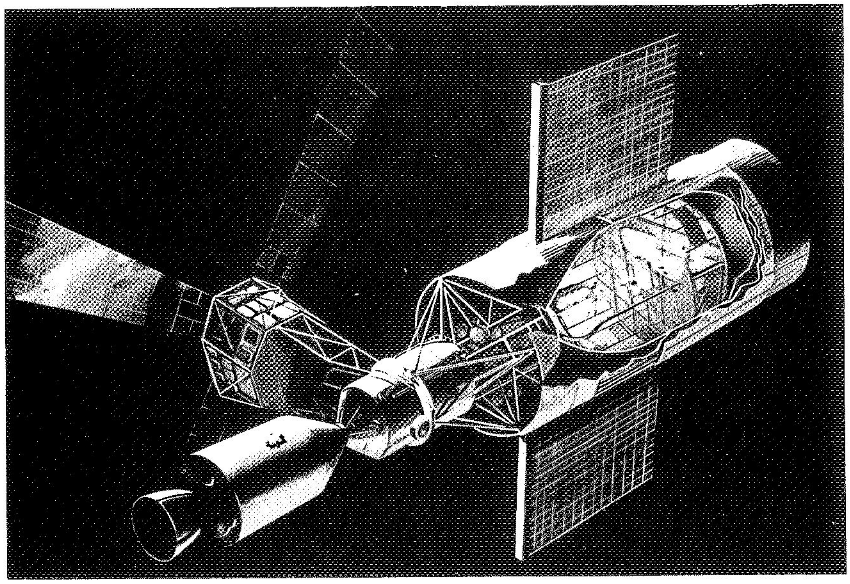
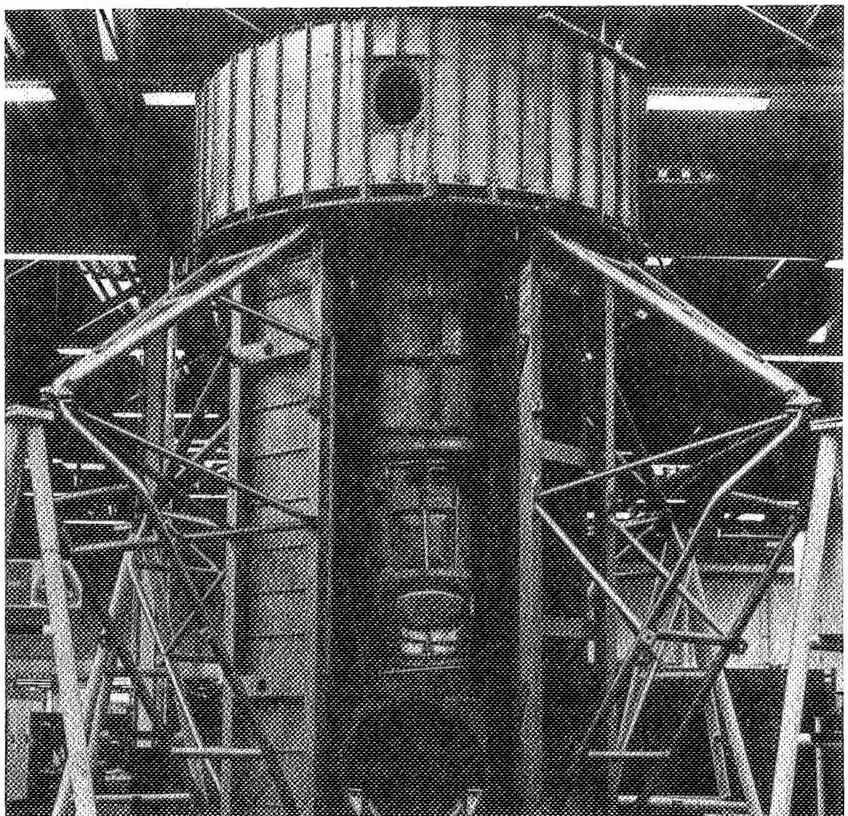


Figure 1–12. Saturn Workshop I concept.

In addition to earlier Preliminary Requirements Reviews on all modules and Ground Support Equipment hardware, an overall Apollo Applications Cluster Technical Systems Review was held at the end of 1969. This review evaluated the impact on the individual module systems and made a technical assessment of the integrated structural, electrical communication, environmental, thermal, and crew systems of the Saturn Workshop I.

Saturn Workshop (Skylab 1).—During the period, the test program was evaluated to make certain that the test plans and results determined for the Workshop launched by a Saturn 1B could be used to the greatest extent possible in the shift to the Saturn V-launched configurations. A major effort was applied to systems design verification and identification of design changes, resulting in establishing test plans to develop and verify the revised hardware designs and sequences.

The Saturn Workshop I engineering mockup was equipped with the Habitability Support System (HSS) in July, and a crew station configuration review was conducted in August. This review, conducted by Government and contractor engineers, crew members, and program and contractor management, resulted in several major improvements. These included the addition of a ground access door and a window, and elimination of the two back-to-back



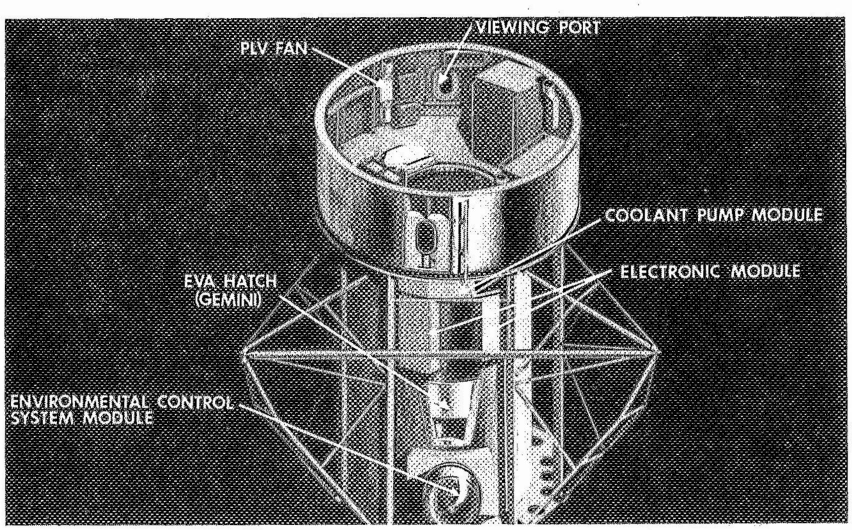


Figure 1–13. The flight article (top) and Airlock Module concept.

floors (the floors will be oriented right side up, with reference to the launch pad).

Since most of the activation crew tasks were deleted, emphasis for neutral buoyancy testing shifted to the in-orbit operational crew tasks. Activity was primarily devoted to obtaining and equipping the neutral buoyancy test article with the special crew quarters and HSS features required to verify work station operations, hardware concepts, and applications. The emphasis for zero gravity testing was also shifted, and the activities were primarily devoted to preparing for and evaluating the HSS related crew tasks. A fecal collector system was evaluated in zero-g in October.

The flight article, S–IVB/IB–212 stage, assigned to the AAP program in April 1969, was taken out of storage. Propulsion and other stage equipment not required, including the after interstage, forward and after skirt, the J–2 engine, cold helium bottles, and other propulsion items were removed.

Airlock Module (AM).—The Agency stressed redefining test requirements and developing revised test plans for the Airlock Systems affected by the program change to the "dry" Workshop configuration. Major changes in the electrical, environmental control, structural, crew provisioning, emergency and warning, and the audio system were analyzed for test impacts. Adding the newly designed gaseous oxygen and nitrogen system and the fixed airlock shroud (which structurally supports the gaseous oxygen/nitrogen systems) will require additional development and qualification test efforts. (Fig. 1–13.)

Static structural tests at the Marshall Space Flight Center were postponed to early 1970; the postponement will allow additional time to evaluate the launch load impacts on the Airlock structure caused by the Saturn V launch vehicle. The same Airlock structural test article will be used for dynamic and acoustic tests. Tests beginning in late 1970 should verify the integrity of the structure and its major installations under launch and docking environments.

Engineers and flight crew personnel, in some 12 flights, conducted three tests of the AM zero-G test articles installed in an Air Force KC–135 test aircraft. These tests verified that crew members have the mobility and capability to operate the Airlock equipment in a gravity free environment.

The Engineering Mockup was revised to the latest "dry" Workshop configuration to include the Fixed Airlock Shroud with its gaseous systems tanks and components.

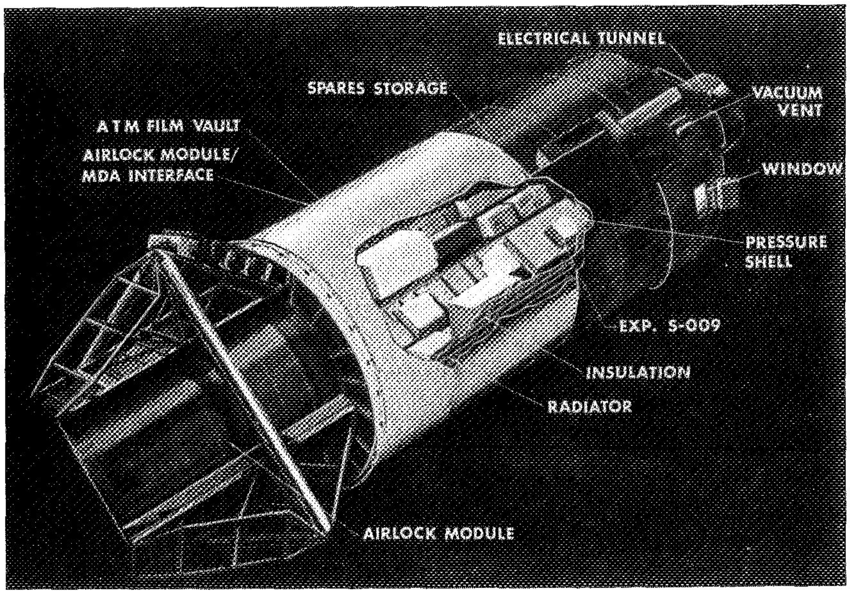


Figure 1–14. Multiple docking adapter.

Multiple Docking Adapter (*MDA*).—The shift to the Saturn Workshop I concept had a significant impact on configurational changes to the Multiple Docking Adapter. The removals (most Workshop experiments and the remote docking station) and additions (Earth Resources Experiment Package, the ATM film vaults, the ATM Control and Display Panel, and the Thruster Attitude Control System Control and Display) affected the structural, zero-G, neutral buoyancy, and components test program. (Fig. 1–14.)

Development testing of MDA components and subsystems started during this period and will continue into 1970; qualification testing of the MDA structure, subsystems, and components will be initiated. The MDA engineering mockup and neutral buoyancy test articles were shipped to the contractor for updating to the latest configuration and preparing them for final verification tests, expected to be run during the second quarter of 1970. (Fig. 1–15.)

Apollo Telescope Mount (*ATM*).—The ATM—one of the major modules of the Apollo Applications Program—provides a stabilized platform for a group of advanced astronomical instruments designed to study the sun. With all its supporting subsystems—electrical power, thermal control, pointing control, instrumentation

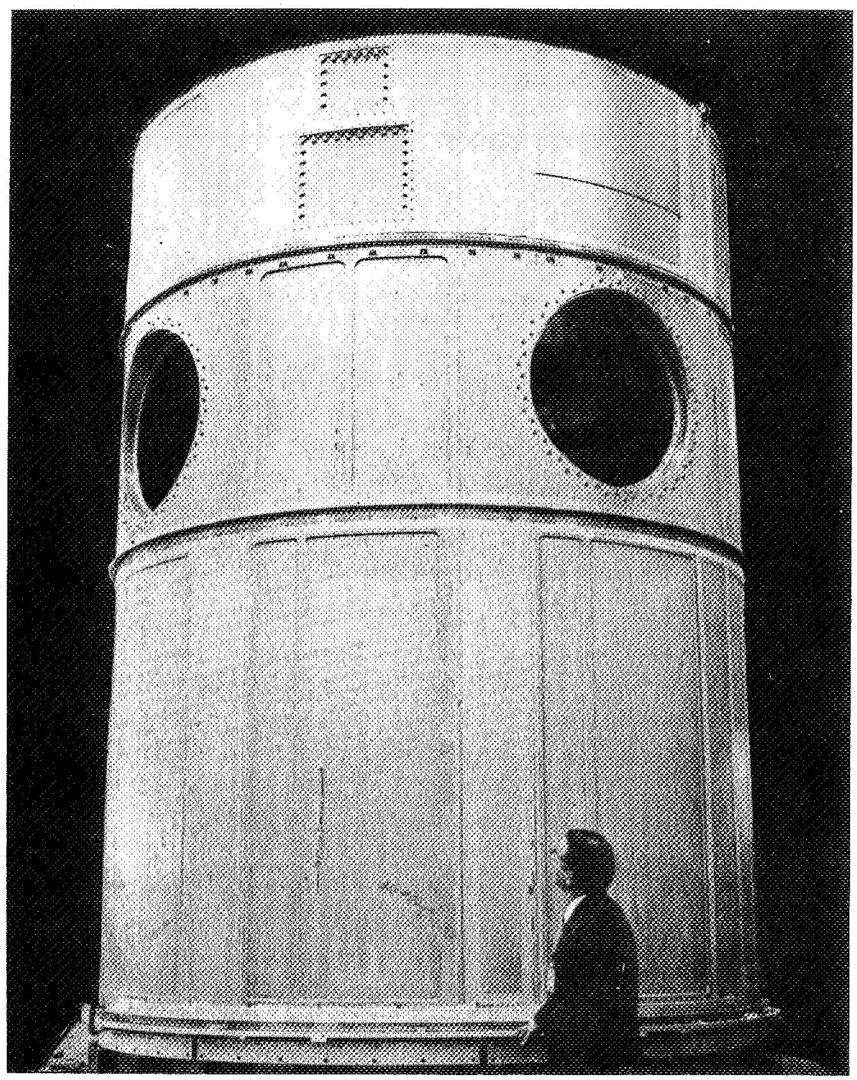


Figure 1–14. Multiple Docking Adapter.

and communication, controls and displays—it becomes a true solar observatory. The major ATM test units—the thermal system unit (TSU) and the vibration unit (VU)—were being fabricated, with the TSU about 80 percent complete and the VU about 50 percent. (Fig. 1–16.)

The principal ATM subsystems were being fabricated, with

many of the flight hardware components already on hand at MSFC. These components should be assembled into deliverable subsystems for the prototype ATM by the end of 1970. By then, most of the flight subsystems will also be assembled and delivered.

The "wet" to "dry" Workshop change resulted in an integrated ATM, thereby affecting the ATM's development. For example, its pointing control system, designed for a 56-day mission, became the attitude control system for the total Workshop and must function for 8 months instead of 56 days. Additionally, the control and display console, previously in the lunar module, was moved to the MDA.

Nevertheless, the development testing of the ATM subsystems was well underway. Among the items undergoing tests were the solar wing deployment mechanism, the film translation and EVA concepts, the control moment gyros, and other elements of the experiment pointing control system. Items previously qualified include the fine sun sensors, the acquisition sun sensors, the tape recorders, and the solar cell modules.

An important milestone in the development of two of the ATM experiments were the rocket flights in November of experiment design verification units—scale models of the experiments which will fly on ATM. The results were excellent, with both flights providing important feedback to the experiment development program.

ATM experiments.—The ATM solar astronomy experiments being developed for the AAP workshop are the White Light Coronagraph, the X-Ray Spectrographic Telescope, the UV Scanning Polychrometer/Spectroheliometer, the X-Ray Telescope, the UV Spectroheliograph, and the UV Spectrograph.

While a certain number of individual tests remain, development testing was nearly completed for the ATM experiments during 1969. The testing was conducted to verify experiment design and to prepare for qualification testing. The development tests include vibration and acoustic tests to simulate the launch environment, and thermal-vacuum and electromagnetic compatibility tests to simulate the in-orbit operational environment.

All of the ATM experiment flight units were being fabricated. They are scheduled to be completely fabricated, assembled, and checked out during 1970.

Command and Service Module.—Effort was underway to redefine the CSM to support the "dry" Workshop mission. The "wet" Workshop CSM had been configured to operate independently of

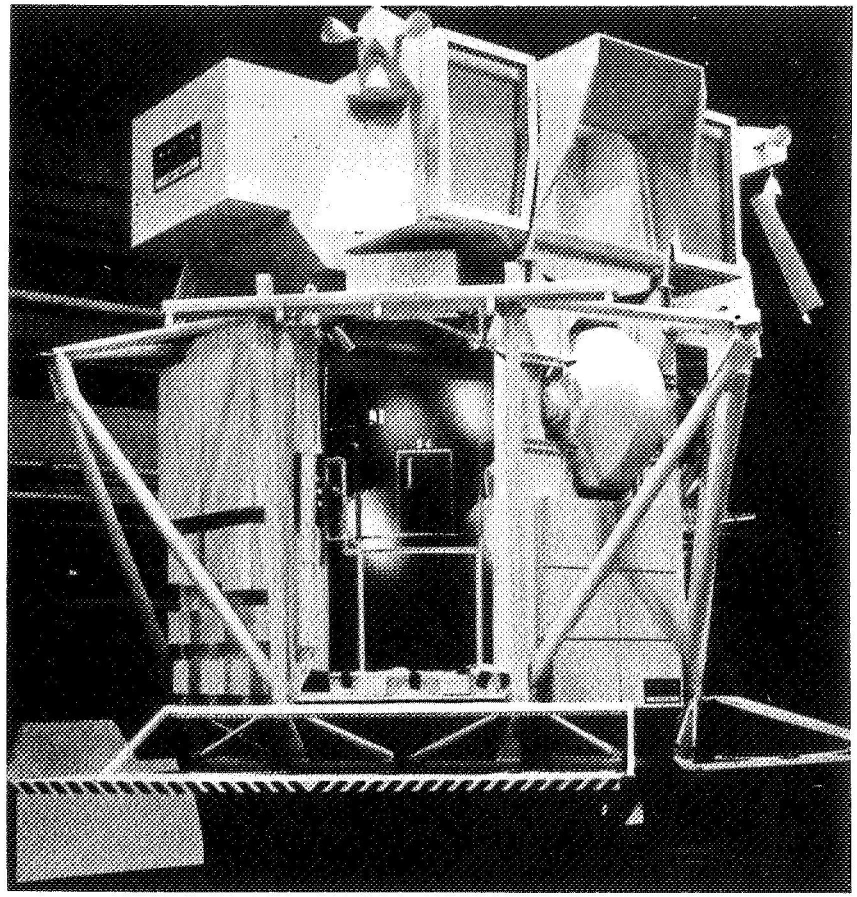


Figure 1–16. ATM mockup.

the Workshop and to supply expendables and provide systems support to the earth orbiting cluster. As a result of the change, the CSM would be powered down to a standby mode during the orbital operations and be reactivated for descent. (Fig. 1–17.)

The dry Workshop CSM concept reduced considerably the requirements for developing and qualifying new and modified systems. Those primarily affected are the reaction control system propellants and pressurization subsystems (to provide a backup deorbit capability) ; the SM Thermal Control System; and the SM structure (to accommodate the modifications). Also, existing critical components previously tested for 14-day missions must be changed to support missions lasting as long as 2 months.

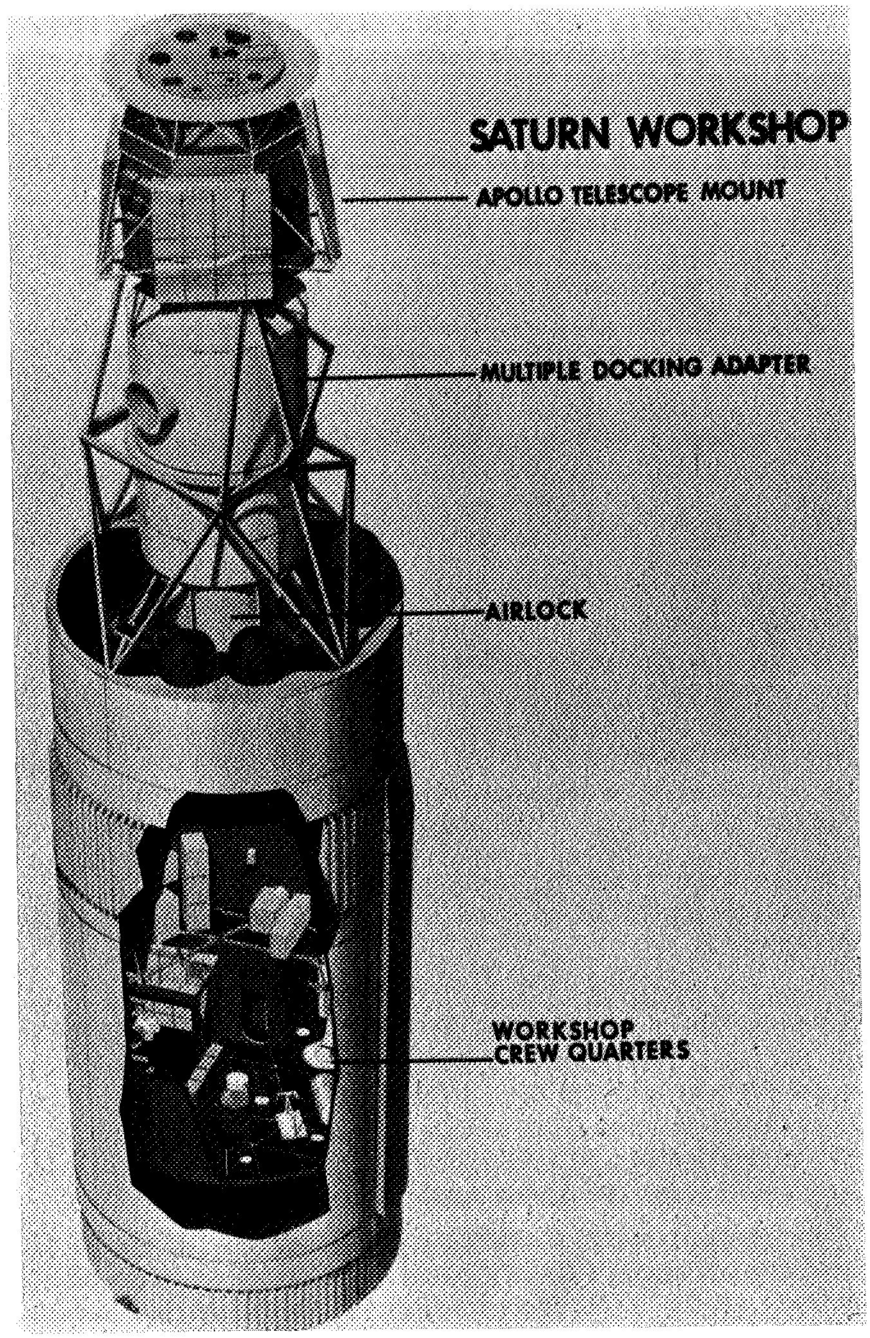


Figure 1—16a. ATM on Saturn Workshop.

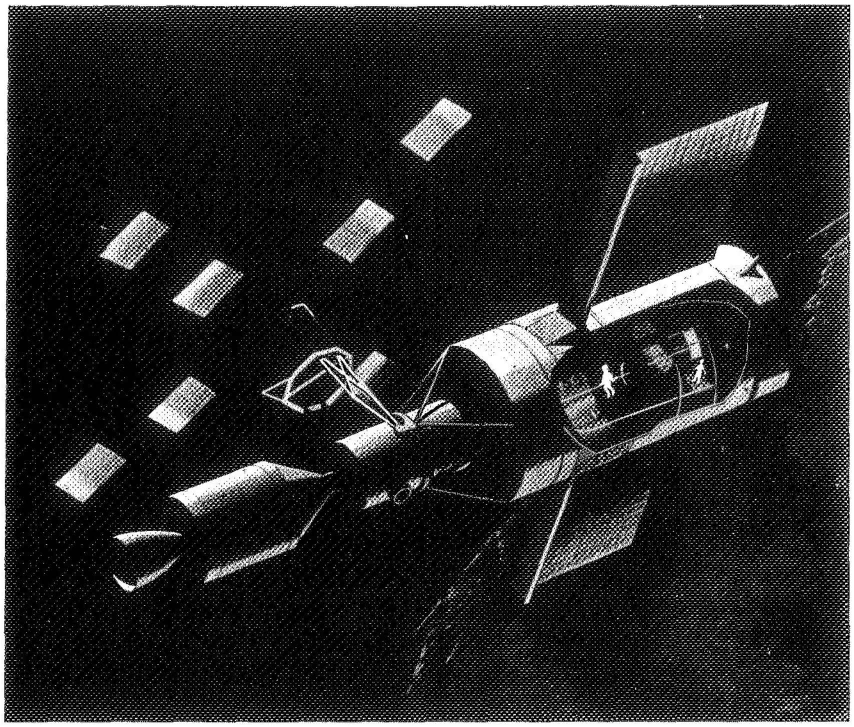


Figure 1–17. Dry Workshop.

NASA began procuring long leadtime test components. Some of the test articles will be provided by Apollo spares and other usable hardware.

Ground Support Equipment.—The dry Workshop concept requires the use of Saturn V launch capabilities and elimination of one Saturn 1B launch pad. The decision was made to use LC–34 because it was qualified during the Apollo program and also because its reactivation costs will be considerably lower. In 1971, it will be reactivated and refurbished to accept the first Saturn 1B launch vehicle for the Apollo Applications (Skylab) Program.

One Apollo Acceptance Checkout Equipment (ACE) station located at a contractor's facility was selected for shipment to MSFC to check out the ATM. Some changes will be necessary to accommodate the ATM checkout, but they will be made without interfering with the Apollo program work of the LM contractor.

Operations

NASA revised its planning documents to reflect the wet to dry workshop change and the change resulting from the increase of the orbital inclination from 33 to 50 degrees. The Agency also began work on a new document, "Operations Directive," which sets forth objectives, constraints, guidelines, and requirements for planning the AAP missions.

NASA began procurement of a Saturn V Workshop Simulator to be developed and used for crew training. When the Manned Orbiting Laboratory (MOL) program was canceled, the MOL systems simulator was transferred to NASA, resulting in a net saving of several million dollars. (The MOL was a Department of Defense program canceled in June 1969.)

ADVANCED MANNED MISSIONS

The Advanced Manned Missions Program is an integrated planning activity directed toward defining and evaluating possible programs, missions, and systems. A key element of this program is a continuous review, updating, and refinement of the manned flight requirements, their relationship to the overall NASA program, and their association with evolving national objectives and advances in both space flight technology and knowledge.

Studies made in 1969 led to the conclusion that it appears feasible to develop a fully reusable transportation system between the Earth and the Moon and that its elements could be adapted for manned planetary exploration. The recommendations of the President's Space Task Group, issued in September 1969, were based on this conclusion.

In consonance with the Space Task Group recommendations, advanced missions studies were conducted to identify major long-range manned space flight objectives and concepts; to propose alternative approaches to achieve these objectives; and to provide guidance for appropriate supporting research and development activities. The following are representative studies:

- *Mission Planning and Activity Scheduling for Long Duration Space Mission.*—The Agency conducted this study to provide a computerized model that could conduct mission in time-line analyses to show the interrelations of spacecraft subsystems, experiment performance, crew skills, and schedules of activity. The completed model permits non-real-time scheduling as intended. Subsequent studies should develop a real-time capability.

• *Saturn V Derivative Launch Vehicle System.*—Engineering and program aspects of a two-stage Saturn V derivative were evaluated. The proposed vehicle, intended for use in the post-1970 time period, could accommodate a variety of manned and unmanned missions. Maximum use of existing flight-proven hardware and of Saturn V manufacturing, test, and launch facilities was stressed to keep down costs. The study showed this concept to be a valid and viable approach to development of an intermediate payload launch vehicle.

• *Space Station Safety Study.*—This study resulted in the development of guidelines identifying crew safety measures to be taken during space station operation and associated activities. These guidelines will help NASA evaluate the impact of safety measures on other space station considerations (cost, design, and operations). Results of this study could also apply to safety problems of other manned space programs.

• *Information Management Systems Study.*—NASA needs an information system to control and condition the total data generated and distributed before, during, and after a space station mission. The four major tasks of the study were developing an earth orbital space program model, establishing information management requirements, determining an information management system approach, and performing an analysis of system alternatives. Results indicated that the decentralized computer system is desirable aboard a space station for reliability and effective programing.

NASA continued working on the technology and development plans for the Space Shuttle and Space Station to avoid redundancy. Based on previously developed technology, the Agency began, or continued, development of those subsystems that would be required for a space shuttle or space station.

The Agency also began developing a prototype long-duration Environmental Thermal Control/Life Support System, and efforts were continued on a redundant strapdown inertial reference unit and an onboard checkout system. Certain habitability mockup work was authorized to help determine improved living conditions for long-duration space flight. The Integrated Medical Behavioral Laboratory Measurement System hardware effort was continued. This system would allow better onboard monitoring and prediction of man's condition during future long-duration flights.

In support of other studies, NASA continued its activity to identify candidate payloads for the Space Station and a possible second

Saturn Workshop. This effort was staffed by a planning team with members drawn from the Manned Spacecraft Center, the Marshall Space Flight Center, the Langley Research Center, and from NASA Headquarters program offices.

Candidate experimental areas for an AAP second Saturn Workshop include building an ATM technology in a continuing program of astronomical investigations; conducting advanced earth observation experiments using the unique capabilities of manned flight; and carrying out biomedical studies directed at further extension of man's ability to live and function in the space environment. Additional possibilities were identified in the areas of bioscience and technology/engineering.

NASA developed and documented a comprehensive candidate experiment program for the Space Station. The document went to the Space Station Phase B contractors who will incorporate it as an intrinsic part of their study efforts. Considerably wider ranging than the second Saturn Workshop effort, this document embraces astronomy, life sciences, physics, applications, and technology/engineering.

In-house payload planning capability was augmented by initiating a contract to investigate requirements for manned space flight experiments. Expected results include significantly increased insight into the problems connected with payload planning for future manned space missions.

SPACE STATION

The Space Station is to be the next major advance in manned earth-orbital flight. It is presently planned for flight in the late 1970's, following the flights of the Apollo Applications (Skylab) Program. (Fig. 1–18.)

During this period, the Space Station activity centered on the Phase B definition of the program. The overall objective of this effort is to obtain the technical and managerial information required so that NASA can choose a single approach to a Space Station from the available alternate approaches. In support of its efforts to define the program, NASA initiated two $2.9 million contracts with industry, one monitored by MSC, the other by MSFC.

To conduct the Space Station Program activities, a task force was organized with the Deputy Associate Administrator of Manned Space Flight as its Acting Director. This Task Force is to manage the program definition effort, prepare the overall in-house

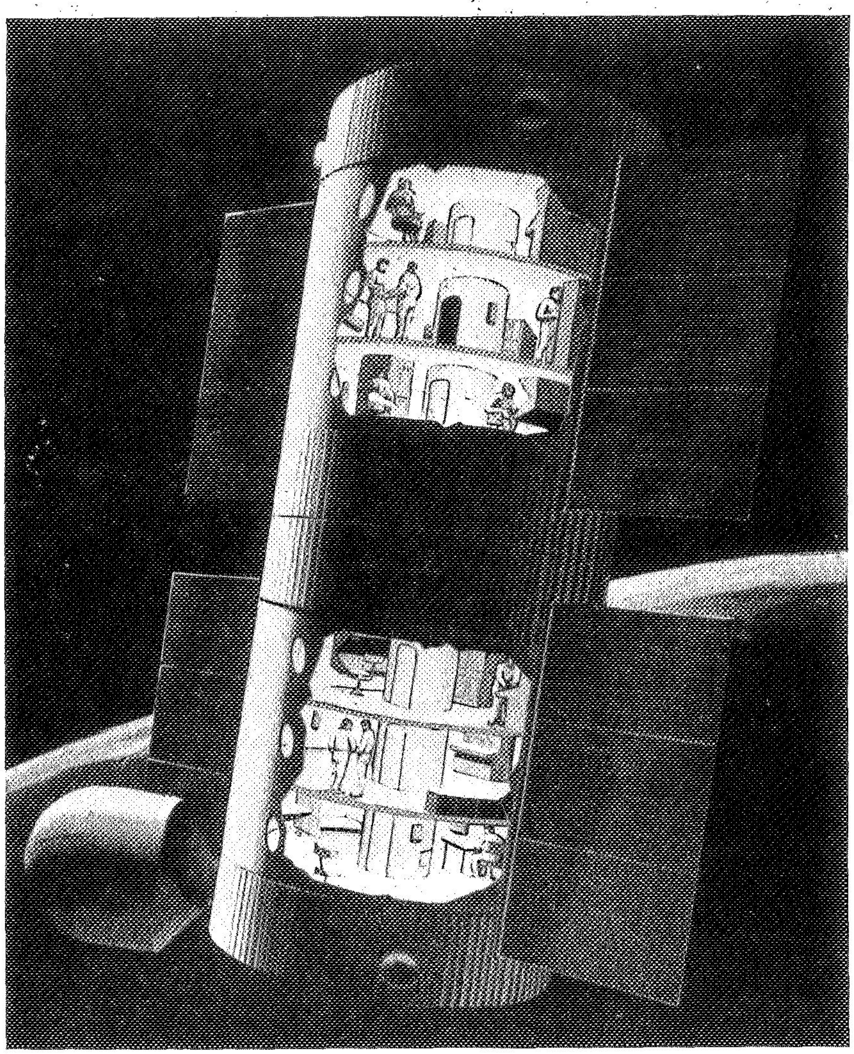


Figure 1—18. Space Station concept.

report evaluating the results of the definition phase, and prepare the plan for later phases of the program. Individuals from all NASA centers are to assist the Task Force. MSC and MSFC established in-house task teams for this specific activity and assigned personnel needed to manage their portions of the effort.

A Space Station technology management team was also organized; it will be directed by the Office of Advanced Research and Technology. The team, composed of representatives of all Centers

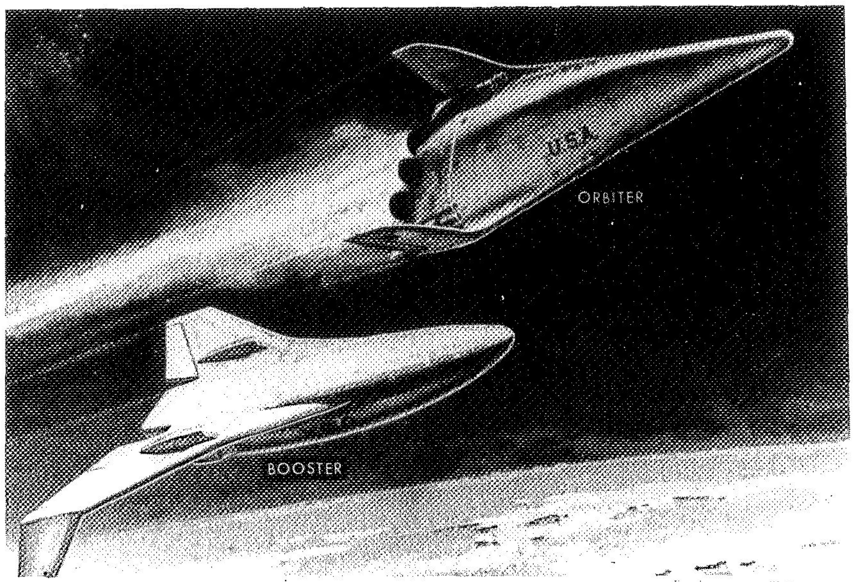


Figure 1–19. Space Shuttle concept.

and Headquarters program offices, is responsible for focusing research and technology to support Space Station developments.

SPACE SHUTTLE TASK GROUP

NASA refined its Space Shuttle objectives, initiated technology study programs, planned management and procurements, and generally defined all major issues and problems.

The Agency decided that the shuttle would be designed so that major systems would be reusable, thus eliminating the partially reusable concept, referred to as the stage-and-a-half, as a phase B baseline characteristic. In addition, the aerospike engine was eliminated from further consideration because it would restrict the flexibility required for vehicle configuration design and not offer any compensating advantage. Further, this engine was not as far along in the development cycle as the bell type engine. (Fig. 1–19.)

Planners and designers fixed an engine sea level thrust of approximately 400,000 pounds as a baseline for further studies. They conducted trade-off studies to determine shuttle configuration characteristics, space traffic and attendant costs, and payload weight and size factors.

Throughout this period, NASA continuously reviewed the shuttle program with DOD to insure maximum DOD participation and

to meet the joint needs of both agencies. DOD representatives attended and participated in the NASA Manned Space Flight Monthly Program reviews, Configuration Design reviews, and other shuttle activities.

In mid-August, NASA assessed the technical progress of the Integral Launch and Reentry Vehicle (ILRV) studies initiated in February. The results of configuration studies and critical design trade-offs were reviewed and then discussed with all five ILRV contractors (four funded, one unfunded). All contractors submitted their final reports by November 1.

The Langley Research Center, the Manned Spacecraft Center, and the Marshall Space Flight Center participated in the subsequent analysis. Along with DOD inputs from its space transportation studies, these ILRV reports will serve as a basis from which the activities for the phase B definition studies will proceed. A Statement of Work and a Request for Proposals of in-depth studies to satisfy future requirements was to be issued to industry in February 1970.

In July, NASA designated its Office of Advanced Research and Technology (OART) to develop a base program from which detailed technology support for the Space Shuttle could proceed. The key technology areas, broadly classified, are propulsion, integrated electronics (avionics), aerodynamics and configuration verification, and structure and thermal protection. OART has since organized for the shuttle technology support and established the following technology panels: Structural Design Techniques, Thermal Protection Sytems and Materials, Dynamics and Aeroelasticity, Propulsion, Aerothermodynamics, Integrated Electronics, Biotechnology, and Operations and Maintenance.

NASA set up a Design Reference Review Board (DRR) to examine issues and deal with problems. In October, a DRR meeting reviewed the major space shuttle issues. This was a follow-on review to one held in September in which technical goals and data requirements were established. These were reviewed in October along with the shuttle engine concept and thrust level, vehicle size, and payload criteria in preparation for the Phase B studies.

A Source Evaluation Board (SEB), composed of both NASA and DOD members, was established in September to prepare for evaluating and negotiating engine definition studies. The Board submitted a procurement plan and started reviewing material for the Phase B proposed Statement of Work. The first approved revision of the work statement prepared jointly by MSC, MSFC, KSC, and OMSF was issued on September 29.

In December, NASA prepared to convene a Source Evaluation Board for the planned vehicle Phase B definition studies. A Project Approval Document (PAD) for the total shuttle effort was also prepared. It defined the integrated work plans, schedules, and resources for both the technology and the systems programs. The document was in the executive review stage as the period ended.

A NASA-DOD-Industry Space Shuttle Symposium was held in Washington, D.C., in October. Its primary objective was an exchange of information on the space shuttle and related technology. Presentations included results of industrial studies, mission studies, and investigations of applicable technology. Appoximately 500 people attended, including 48 representatives of eight different foreign countries. Twenty-nine scientific papers were presented in three technical sessions over a 2-day period. Subjects emphasized were engine development, reentry heat protection, and the development of an autonomous on-board checkout and control system.

MISSION OPERATIONS

Mission operations activities were concerned with flight crew training and support, launch and flight operations support, mission control systems, launch information systems, and the Huntsville Operations Support Center.

Although operations support necessarily grew because of the four Apollo launches during 1969, Mission Operations devised plans for reducing it after the first lunar landing. Such reduction was made possible by the reduced manned mission launch schedule (two per year) and the proved capabilities of the overall support complex.

Flight Crew Operations

The successful Apollo 11 and 12 missions were the result of an extensive and varied training program for the flight crews. All elements required for training were operational and supported the effort in an outstanding manner.

Flight crew assignments for Apollo 13 and 14 were made and specific mission training for each was begun.

Cancellation of the U.S. Air Force's Manned Orbiting Laboratory (MOL) resulted in the availability of a group of qualified astronauts from which NASA selected seven MOL astronauts for its active astronaut force. By special agreement, three of those selected, who were attending graduate school, will complete this work (two Ph.D.'s and one M.S.) before reporting to NASA.

AAP Data Relay Terminal Study

The mid-1969 decision to launch the first AAP Workshop in a "dry" configuration with a Saturn V booster eased the Workshop weight and space constraints. NASA proposed and supported a study for adding a communications terminal on the Workshop to operate through the INTELSAT relay satellites which would be available in time for the scheduled Workshop launch.

Communicating through relay satellites offers the primary advantage of near-continuous communications access between the spacecraft and the ground, which, in turn, increases data transmitting capacity, mission flexibility, and mission safety. Without relay satellite support, the Workshop would be in contact with the ground only about 30 percent of the time.

NASA completed the AAP Data Relay Terminal design study in December. No major technical problems were identified. The Termal hardware is a straight-forward application of current technology, estimated to cost less than $10 million. However, because of unknown costs to integrate the Terminal into the overall workshop configuration and possible schedule slippage from the launch date, NASA decided not to include the Terminal in the first Workshop. Possible application to a second Workshop must await further clarification of the AAP program.

Operations Support Requirements

Through its Support Requirements Office, NASA continued its Agency-wide study to consolidate and delete support requirements. Immediately after the successful Apollo 11 mission, it made the following deletions: C-Band radars at Patrick AFB, Grand Bahama Island, Grand Turk Island, Antigua, Ascension, Pretoria, Hawaii, California; Unified S-Band at Grand Bahama Island, Antigua, Guaymas or Texas; VHF telemetry at Grand Bahama Island, Antigua, Guaymas or Texas, Tananarive; and air-to-ground voice at Grand Bahama Island, Antigua, California, Guaymas or Texas, and Tananarive. Three Apollo ships were taken out of service and returned to Department of Defense (the Redstone, Mercury, and Huntsville), as were four Apollo Range Instrumentation Aircraft (ARIA).

NASA continued its associate membership on the DOD-sponsored Inter-Range Documentation Group (IRDG). This group made some progress in the further design of the Universal Documentation System (UDS) which will ultimately give a standard and common format for all Requirements/Support documentation.

Mission Control Systems

The Mission Control Center (MCC) at Houston completed premission program development, system testing, and mission simulations and provided real-time flight control for Apollo 11 and 12. The first lunar landing mission (Apollo 11) in July climaxed development activities and indicated the amount and kind of sustained support required for follow-on lunar missions such as Apollo 12, launched in November.

Early in 1969, NASA realized that it would be both possible and necessary to reduce premission program development and mission support requirements for follow-on lunar missions; therefore, it initiated an intensive effort to identify areas where support costs might be reduced. As a result of this effort and the experience gained on Apollo 11, it reduced the MCC computer complement by two units; one Mission Operations Control Room (MOCR) was placed in "mothball" status; and the Apollo Simulation Checkout and Training System (ASCATS), moved to a converted warehouse at the beginning of the Apollo program, was moved back into the MCC, resulting in more efficient use of computer software and hardware systems. In addition, NASA reduced the number of contractor employees supporting MCC operations.

NASA continued to develop the Digital Television Equipment (DTE). As tentatively planned, the DTE will replace the present optical system by 1972 to provide improved quality displays while requiring less maintenance, floor space, power, and air conditioning.

The ALSEP control room provided support for the Early Apollo Scientific Experiment Package carried on Apollo 11 and for the ALSEP deployed by Apollo 12. This ALSEP facility has only those systems which are essential to support the ALSEP. Work was completed on the Communication, Command, and Telemetry System (CCATS) restart system to provide both rapid switch-over to a backup CCATS computer in the event of prime computer failure and more efficient use of computer resources.

The spacecraft TV scan converter project was completed, as was the Computer Aided Communications Analysis System project which provides real-time prediction of spacecraft communications performance. NASA used the latter in support of Apollo missions 11 and 12 to provide flight controllers information needed to determine the optimum on-board equipment configuration and operational modes for each mission situation. The system provides capa-

bilities for syntheses and post-mission data analysis as well as real-time performance predictions.

A color television scan converter, developed along with the modified commercial format color television system flown for the first time on Apollo 11, was tested and placed in operation at MSC. This system is unique in that basically three standard commercial TV pictures are combined in a prescribed manner so that the original image coloring can be reconstituted. Performance evaluation of a large-screen color TV projection system was completed, and the system was installed in the MCC for use during Apollo 11. The system makes it possible to receive color television transmissions such as those from the color television scan converter for projection on a large screen in the Mission Operations Control Room (MOCR) for use by the flight controllers and the mission director.

In the spacecraft-to-ground communications system compatibility area, NASA conducted investigations of system anomalies observed during Apollo missions and used the laboratory communications test system to establish proper operating modes, system configuration, and design limitations in each encountered situation. The responsible hardware groups used the resulting problem solutions to make corrections.

Launch Information Systems

Launch Information Systems at KSC provided prelaunch and launch ground instrumentation, telemetry support, data processing, operational communications, and calibration services for Apollo 11 and 12. They also provided support for NASA unmanned launches and some DOD launches from AFETR. Following Apollo 11 in July, an Apollo launch interval of 4 months was established and contractor manpower was reduced 15 percent.

NASA continued its effort to improve prelaunch voice communication quality and coordination of systems interfaces. A Mission Operations Directive issued in November 1968, assigned KSC lead center responsibility for prelaunch communications; on July 25, 1969, KSC issued an intercenter implementation plan. This intercenter working agreement, the minor systems changes, and the overall systems configuration drawings resulted in significantly improved performance of the prelaunch voice communications system for Apollo 11 and 12. NASA continued its effort to eliminate remaining voice-operated switching devices in the KSC voice path to the spacecraft to improve voice communication reliability; these were being removed in preparation for Apollo 12 support.

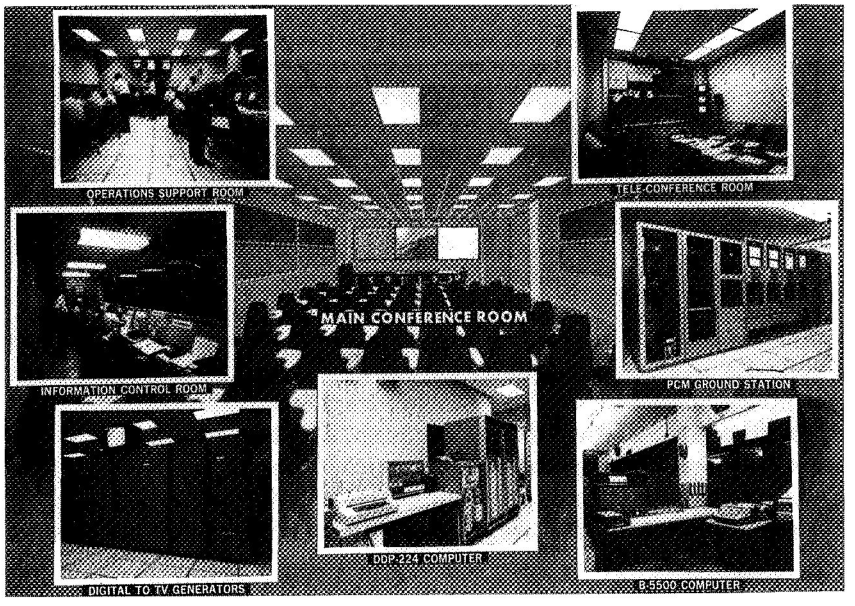


Figure 1–20. Huntsville Operations Support Center.

Huntsville Operations Support Center

The MSFC Huntsville Operations Support Center (HOSC) provided prelaunch and launch support to KSC and mission support to MSC for Apollo missions 11 and 12. MSFC cut the HOSC operations cost nearly 50 percent for fiscal year 1970 by reducing contractor support, reducing communications costs, and freezing hardware configuration (fig. 1–20).

SPACE MEDICINE

NASA's space medicine activities continued to support the various aspects of manned space flight in the specialized areas of biomedicine and bioenvironmental engineering. The Director of the program also continued to carry out administrative actions associated with extraterrestrial exposure.

Quarantine operations were conducted successfully for Apollo 11 and 12. After a detailed study of the biotest and relevant geochemical and geological findings, however, NASA concluded from available evidence that lunar materials represent an extremely low probability of hazard to this biosphere; quarantine, as applied to lunar exploration, could be safely discontinued. The Interagency

Committee on Back Contamination (ICBC) supported this position, but a special panel from the National Academy of Sciences recommended that quarantine be invoked for Apollo 13 because of the new highland environment and deep core sample to be taken. Therefore, NASA decided to continue quarantine for Apollo 13. If nothing new, significant, or relevant were found, the quarantine would be discontinued although the sample would continue to be biologically characterized.

Apollo Clinical Experience

The 5,000 plus man-hours of exposure to space flight through Apollo 12 have added greatly to knowledge of man's response to the space environment. The spacecraft environment has been maintained in a suitable range for man, and the radiation environment has been benign in the absence of solar flares. Crews have generally adapted to weightlessness and used its advantages.

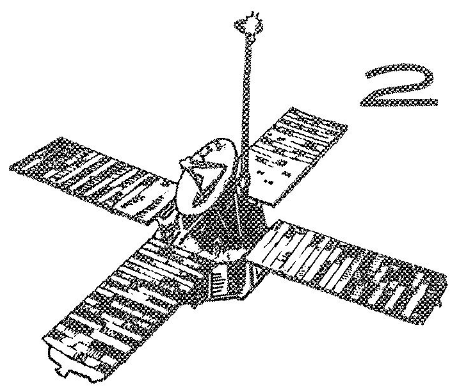
Improvements in inflight food have evolved with the addition of moisturized packs and such items as sandwiches and dried fruit. Crew weight loss not entirely caused by fluid loss is still noted. The methods of supplying potable water have been effective. Progress has also been made in removing dissolved gases from the drinking water supply, as reported in earlier flights. (Ch. 4, p. 108.) Waste management remains an area that requires further design efforts. Work/sleep cycles have improved with the adoption of simultaneous sleep periods and with constant effort in mission planning to keep the sleep periods related to crew cycles in training. The medical kit has been adequate, with the contents being adjusted as the need arose. Bioinstrumentation has functioned well.

A preflight preventive medicine program was implemented to reduce preflight, inflight, and postflight diseases. Infectious illnesses, usually viral-type upper respiratory or gastrointestinal, were noted in all these periods on early missions. Motion sickness was noted in varying degrees, but all crews adapted well to space flight. Some cardiovascular deconditioning has been noted postflight in response to provocative testing of the cardiovascular system. This finding has been similar in degree and duration to that noted after the Gemini flights. A decrement in work capacity tests similar to that in Gemini has been noted immediately after the flight and has lasted 24 to 36 hours.

Astronauts conducted lunar-surface activity at less than predicted energy costs. The average hourly by-energy expenditure expressed in British Thermal Units (and commonly called the metabolic rate) was estimated as follows for Apollo 11 and 12:

	Extra Vehicular Activity I (Btu/hr.)	Extra Vehicular Activity II (Btu/hr.)
Apollo 11:		
Command Pilot	900	---------
Lunar Module Pilot	1,200	---------
Apollo 12:		
Command Pilot	975	875
Lunar Module Pilot	1,000	1,000

Based upon this metabolic information NASA is considering extending lunar surface extravehicular activity in Apollo 13 and subsequent missions.



2

SCIENTIFIC INVESTIGATIONS IN SPACE

The Nation's space program made far-reaching contributions to science during recent months. Astronauts set up a geophysical station on the moon to transmit data to earth and brought back samples of the lunar surface for analysis; two spacecraft flew past Mars to collect extensive data; and scientists received invaluable physiological data from an instrumented Biosatellite carrying a primate.

PHYSICS and ASTRONOMY PROGRAMS

Orbiting Observatories

Orbiting Solar Observatory–6, launched on August 9, resembles earlier spacecraft of this type but scans the solar disk better from a similar orbit. It weighs 640 pounds and is spin-stabilized (fig. 2–1). Its stabilized "sail" section is able to point, with an accuracy greater than one minute of arc, at 16,384 points in a grid over the solar disk. This sail carries an ultraviolet spectrometer-spectroheliometer developed by the Harvard College Observatory and X-ray spectrometers developed by the Naval Research Laboratory. The Harvard instrument can be programed from the ground on an orbit-by-orbit schedule as needed for "real time" scientific analysis.

On the "wheel" of OSO–6 are a British instrument to study important solar helium spectral lines, an Italian one to measure solar X-rays and cosmic gamma rays, and three American instruments to measure solar X-rays, zodiacal light, and neutrons. All of these provided data as planned.

On December 7, Orbiting Astronomical Observatory–2 completed a year in orbit (*20th Semiannual Report*, p. 56, and *21st*

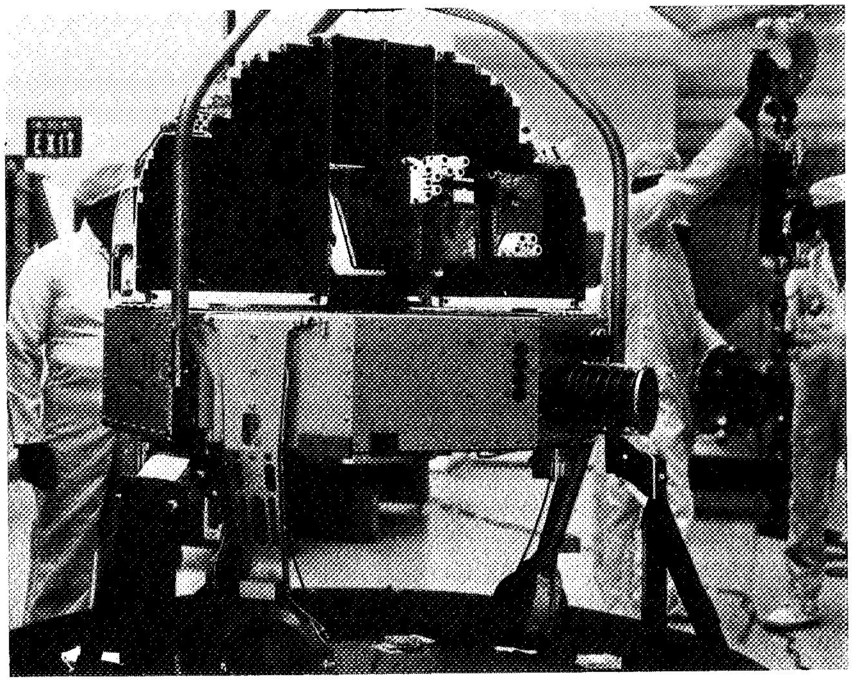


Figure 2–1. OSO–6.

Semiannual Report, p. 50). The Smithsonian celescope on board has taken over 6,000 pictures of the celestial sphere; the Wisconsin-designed instrument has observed 762 celestial objects and transmitted data in geophysics, stellar astronomy, and interstellar matter in the ultraviolet energy range. Data received on Mars were being compared by scientists with information supplied by the Mariner Mars missions (p. 56).

In December, the fifth Orbiting Geophysical Observatory completed the first total sky survey of hydrogen Lyman/alpha radiation. (OGO–5 was launched in March 1968.) This radiation—emitted by hydrogen at 1,216 angstroms—indicates the presence of neutral hydrogen gas around the sun and the existence of several strong sources in the Milky Way. The measurements, obtained by an ultraviolet photometer of the University of Paris, were made possible by the highly elliptical orbit of the satellite (perigee 186; apogee 92,000 miles).

AZUR Satellite

The first cooperative satellite with West Germany, AZUR, was

launched on November 7 to study the trapped radiation belts (ch. 7, p. 140). Placed in a nearly polar elliptical orbit at altitudes up to 1,600 miles, it carries eight instruments developed in German laboratories for measuring magnetic fields, protons, electrons, and a band of ultraviolet radiation between 3,000 and 3,900 angstroms.

Second Airborne Auroral Expedition

An 85-hour study of the Aurora Borealis (the Northern Lights) and the polar cap airglow was made from a NASA jet airplane between November 20 and December 8. The Canadian Churchill Research Range, Fort Churchill, Manitoba, was the primary operating base, with other flights from Fairbanks, Alaska, and Bodo, Norway. Instruments of NASA, ESSA, several universities and industry, as well as from Canada and France, and TV and photographic equipment were aboard the aircraft, which was staffed by scientific teams from the United States, Canada, and France. The 14 instruments carried out measurements in spectrometry and broadband photometry from the near ultraviolet to the infrared, riometry, and magnetometry. Most of the 15 flights included coordinated measurements with overpasses of the OGO–6 satellite and the geostationary ATS spacecraft.

The results of this study confirmed those of a similar one in January–March of 1968 (*19th Semiannual Report,* p. 42) and provided new data. For example, flights from the Norwegian base could be made during total darkness to observe geomagnetic midday auroras.

Sounding Rockets and Balloons

Sounding rockets were continuing to play an important role in space research and in testing instruments to be flown on satellites. Twenty-five launches were made—among them simultaneous tests during a solar flare of two instruments being developed for the Apollo Telescope Mount, and tests of an improved solar X-ray telescope-proportional counter spectrometer, and a near-ultraviolet high resolution spectograph. There were also 24 balloon launchings, the most important of which was a successful engineering test of major mechanical components of the Stratoscope II optical stellar telescope. This instrument is being developed for very high quality photography from above the lower atmosphere. In addition, a number of the balloons carried equipment to measure heavy cosmic-ray ions and electrons.

APOLLO 11 SCIENCE SUMMARY

To meet the scientific objectives of the first manned landing on the moon, the Apollo 11 astronauts were assigned a number of

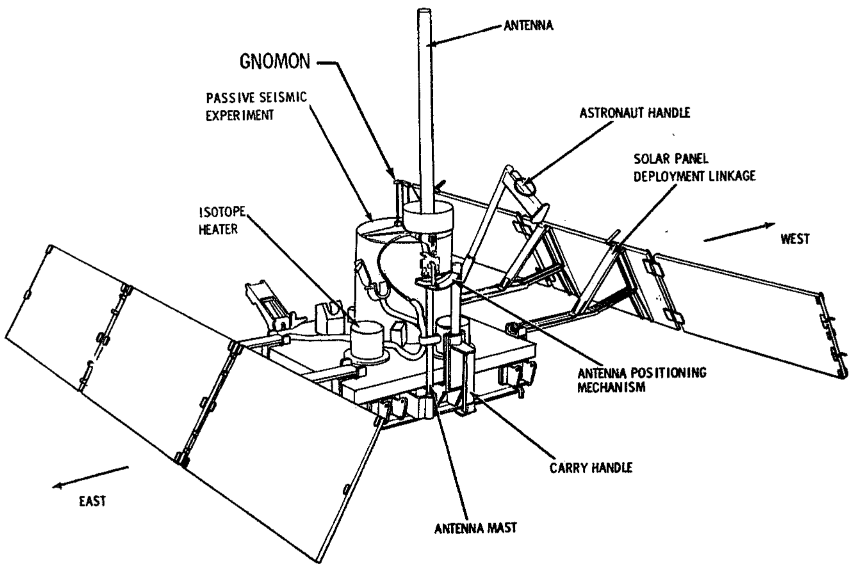


Figure 2–2. Passive seismic experiment package.

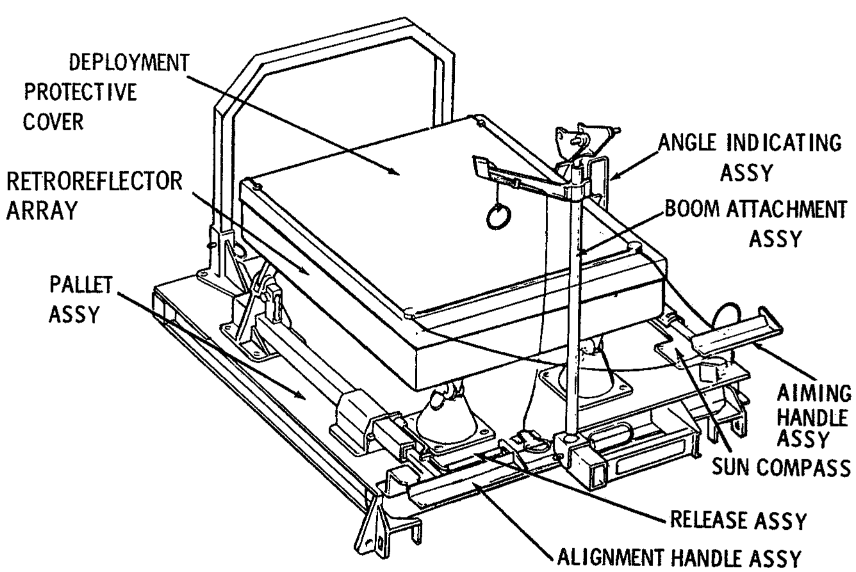


Figure 2–3. Laser ranging retroreflector experiment.

Figure 2–4. Solar wind composition experiment.

tasks, which they carried out during their stay on the lunar surface (p. 4). All of the objectives were achieved. (Fig. 2–2 through 2–4.) The accounts of the scientists who examined the lunar samples and the observations of the astronauts who collected them are detailed in the *Apollo 11 Preliminary Science Report* (NASA SP–214, app. N).

APOLLO 12 SCIENCE SUMMARY

Lunar Surface Experiments

The first ALSEP was set up by the Apollo 12 astronauts. It is discussed in chapter 1 (p. 10) and shown in fig. 2–5. The ALSEP

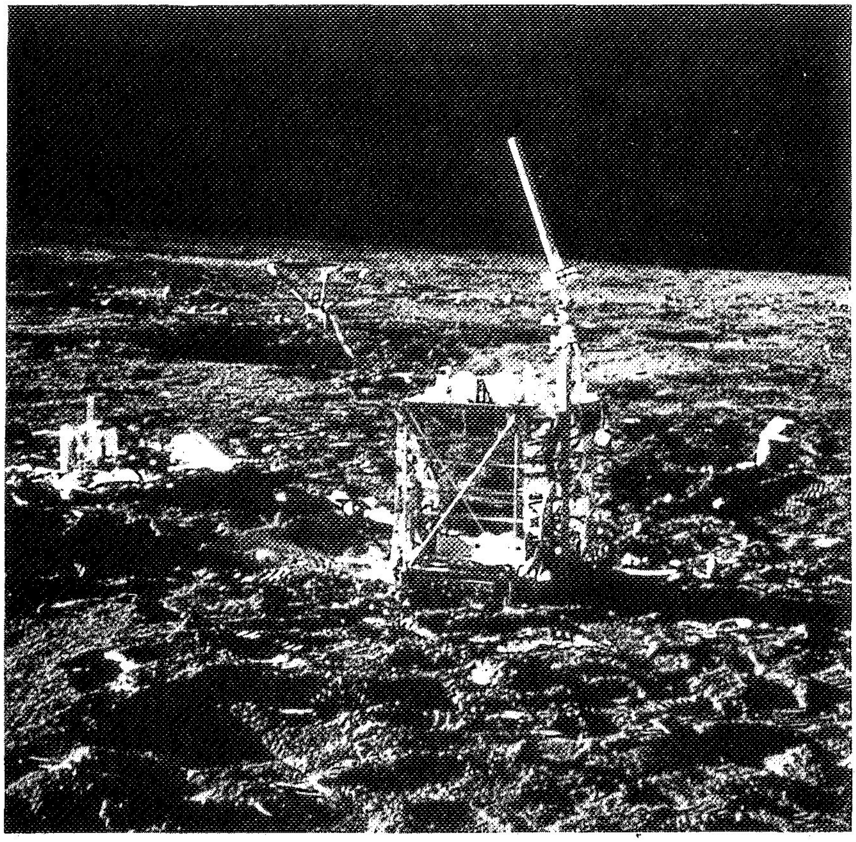


Figure 2–5. First ALSEP.

passive seismometer (fig. 2–6) records waves traveling through the moon's body or along its outer surface. It recorded the astronauts' footsteps and other activities, and, after they left, over 30 unexplained long duration events. Some signals received lasted for more than 20 minutes—some up to 40 minutes. The shocks recorded were small in comparison to major earthquakes (about 3 on the Richter scale of 10, in contrast to the 1964 Alaska earthquake which registered an 8.3) and might have been caused by meteoroid impacts rather than internal moonquakes.

Another instrument, the *lunar surface magnetometer* (fig. 2–7), measures the moon's permanent magnetic field and the one caused by the interaction of the moon with ions and electrons of the solar wind. (If the moon is a perfect insulator, the solar wind particles will not induce a magnetic field. If the lunar material acts as an electrical conductor, the particles can cause a magnetic field

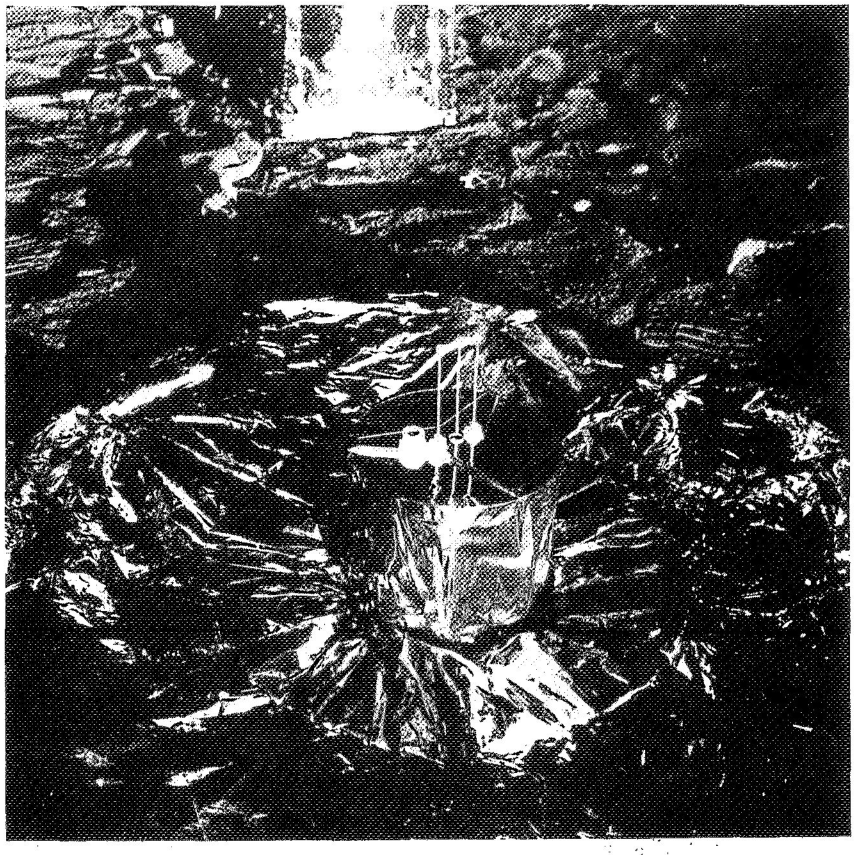


Figure 2–6. Passive seismometer on the moon's surface.

to be induced in the moon. This is due to the fact that when electricity flows through a body a magnetic field is generated.) When the magnetometer passed through the magnetosphere of the earth, it recorded an increase in the lunar field of from 30 to 45 gamma. And as the moon passed from this region into interplanetary space, it moved through a transition zone—the normal field bouncing on three occasions to 80, 90, and 120 gamma. Each of these lasted for about 3 minutes with several hours between "bounces." The data, being analyzed at Ames Research Center, should lead to a better understanding of the influence of the solar wind on earth's magnetosphere and the method by which it is decelerated and deflected around the magnetosphere.

The lunar surface magnetometer data will be used to estimate the internal lunar temperature, contributing to a better under-

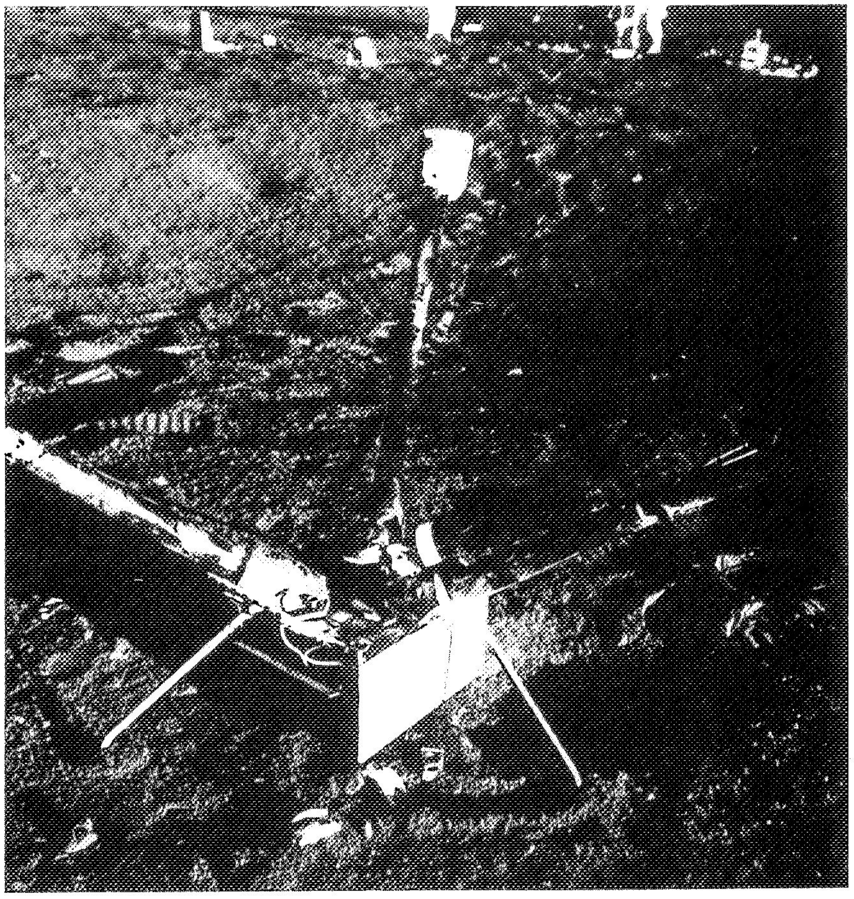


Figure 2–7. The lunar surface magnetometer.

standing of the moon's origin and history. (Preliminary data indicate a field of between 30 and 45 gamma.)

The *solar wind spectrometer* (fig. 2–8) measures the density and direction of protons and electrons from the sun which reach the lunar surface. Knowledge of the solar wind will contribute to understanding of the sun and the physical processes at work on it, and to knowledge of the moon's magnetic field and atmosphere.

The *lunar atmosphere detector*—a cold cathode ionization gage (fig. 2–9)—is essentially a pressure gage. It was designed to measure the density of neutral particles to provide information on pressure at the moon's surface. (The instrument operated for 14 hours and shut itself off. Causes of this failure were being investigated.)

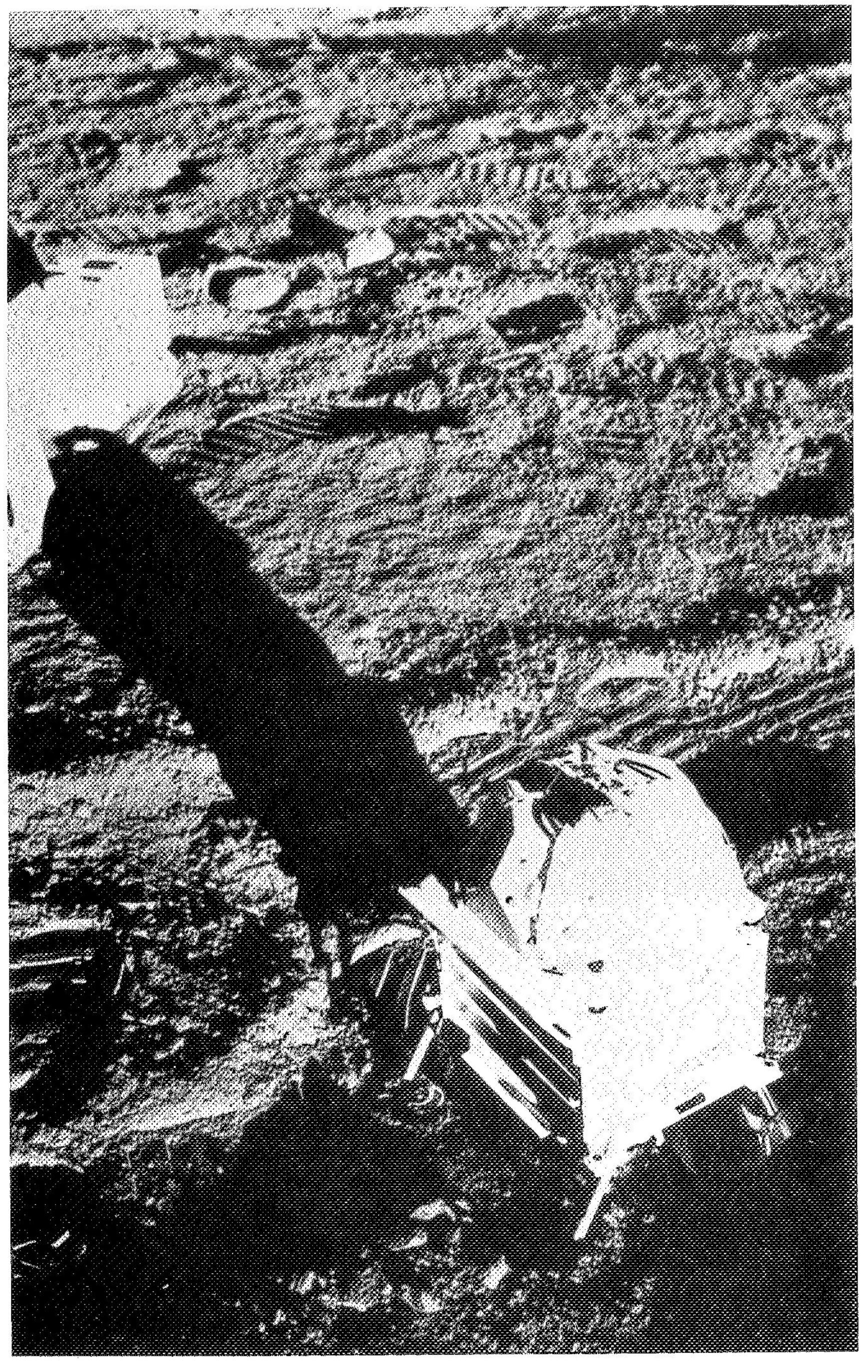


Figure 2–8. Solar wind spectrometer.

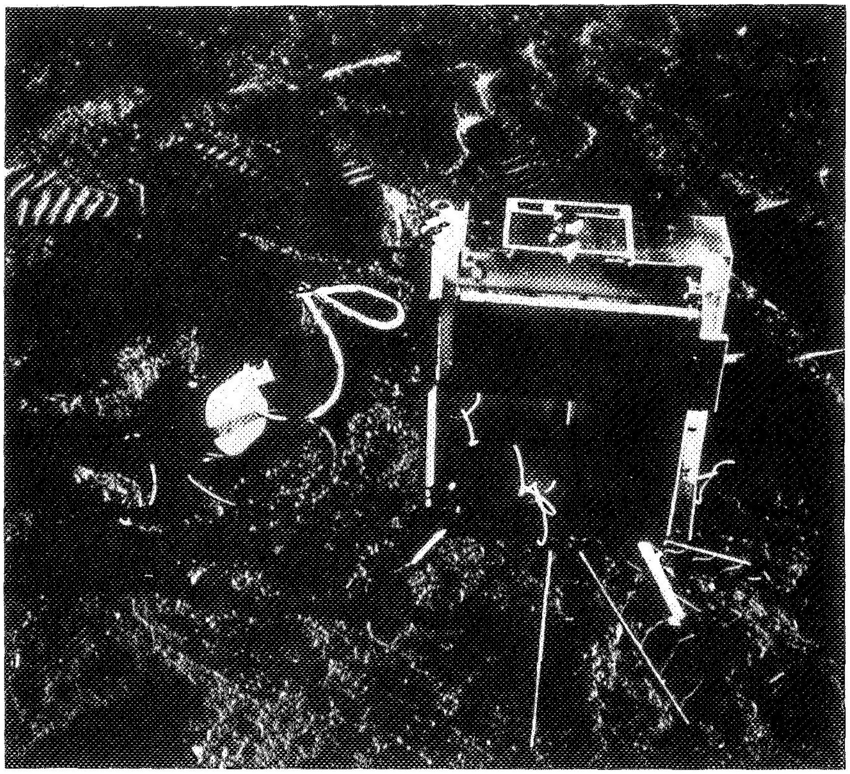


Figure 2–9. Suprathermal ion detector.

In addition to the ALSEP experiments, the Apollo 12 mission repeated the *solar wind composition experiment* of Apollo 11 (fig. 2–10). This time the aluminum foil was exposed on the lunar surface for 18 hours and 40 minutes. Ten times as many solar wind particles were expected to be trapped during this long exposure time.

Lunar Surface Samples

During two 4-hour periods of exploration (EVA's) the astronauts collected contingency, selected, documented, and tote bag samples from the moon's surface to be returned to the Lunar Receiving Laboratory at Houston for analysis. The contingency and selected samples were collected early in EVA–1. Documented and tote bag samples were gathered during the second EVA.

The Lunar Module landed in the eastern part of the *Oceanus Procellarum* (Sea of Storms) on the northwest rim of the crater in

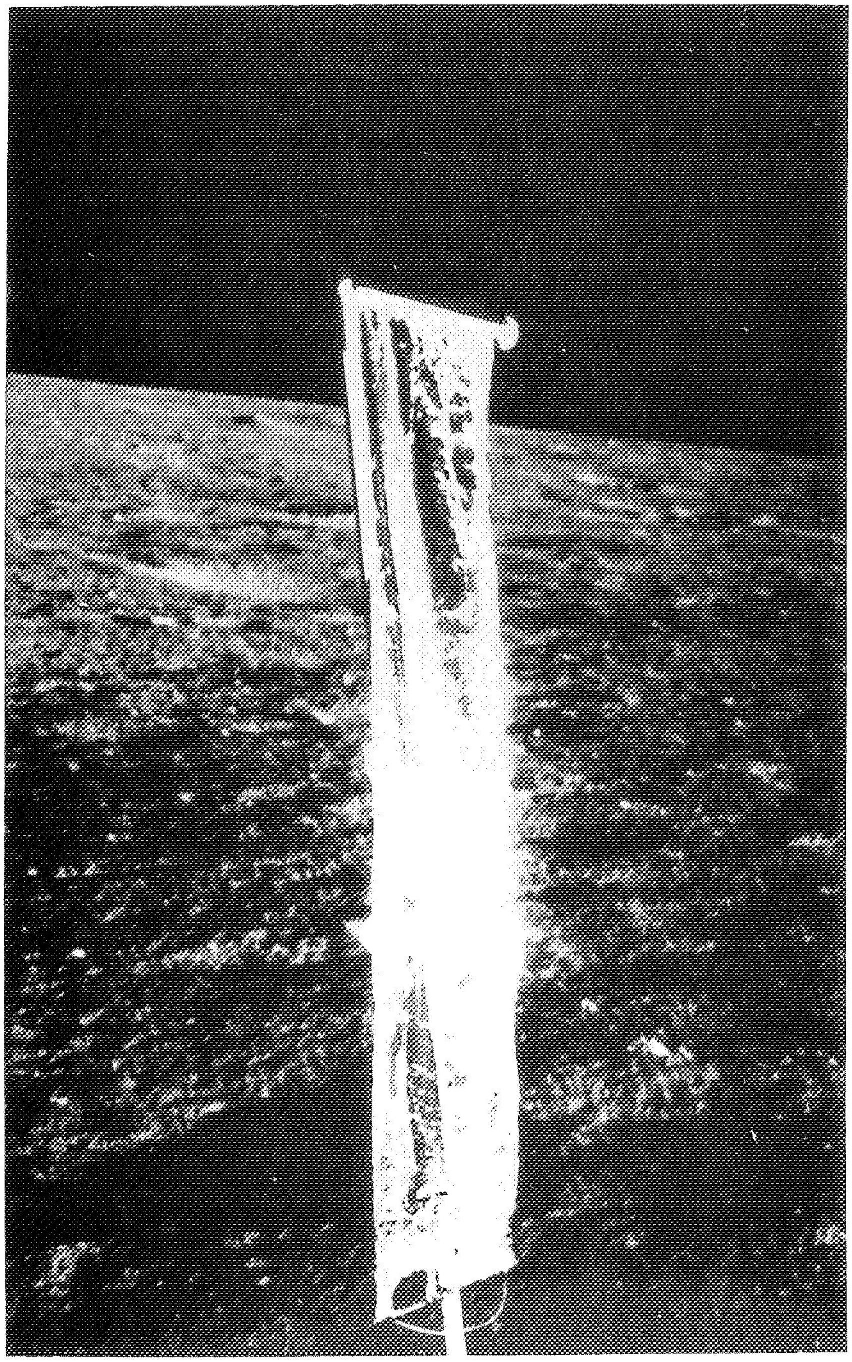


Figure 2–10. Solar wind composition experiment.

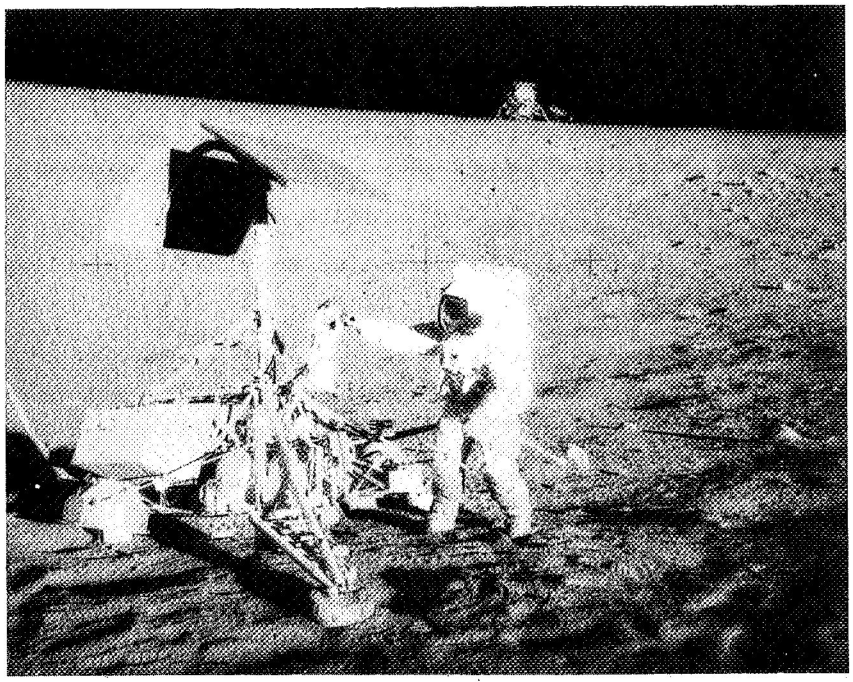


Figure 2–11. Apollo 12 LM and Surveyor 3.

which the unmanned Surveyor 3 touched down on April 20, 1967 (fig. 2–11). The site is among a cluster of craters from about 150 to 1,200 feet in diameter, several of which the astronauts examined. They collected samples from the rims of the craters and their ejected deposits, as well as specimens which may have originated some distance from the landing site and been thrown into the area from a meteor impact.

Scientists found the surface in this region to consist of a layer of fragmental debris made up of particles ranging from those microscopic in size to blocks several feet across. They also discovered marked differences between the specimens from the Apollo 11 and 12 landing sites. Samples collected during the Apollo 12 mission varied widely in composition and texture, whereas Apollo 11 specimens were much more homogeneous in composition and consisted largely of breccias (rocks made up of smaller pieces "cemented" together). Very few breccias were returned with the Apollo 12 samples.

A detailed preliminary science report of the Apollo 12 mission will be published in the near future.

Biology and Organic Chemistry

No viable organism has been found in the lunar samples, nor any evidence of previous living or fossil material. Naturally occurring organic matter was present in extremely small amounts (no more than 10 to 200 parts per million). Studies of the specimens were continuing.

PLANETARY PROGRAMS

Mariner Mars 1969

Early in the report period two Mariner spacecraft flew past Mars collecting and transmitting the most comprehensive data on a neighboring planet yet provided. The Mars flyby marked the successful completion of NASA's Mariner Mars 1969 program and paved the way for future planetary exploration (*21st Semiannual Report*, p. 57).

In the evening of July 29, Mariner 6 started its investigation of the planet by photographing the entire surface of Mars exposed to the television camera during a 2-day cycle. Near encounter operations began July 31 as the spacecraft came within 2,150 miles of the surface (fig. 2–12). Its instruments—including an ultraviolet spectrometer, infrared spectrometer, and an infrared radiometer in addition to two TV cameras—continuously scanned the surface, collecting and returning information to the Goldstone, Calif., tracking station in real time. By the time Mariner 6 crossed the lighted side of Mars and entered into the planet's occultation shadow, about 60 far-encounter photographs were obtained; 25 overlapping high- and low-resolution pictures were acquired as the spacecraft passed over the equatorial region of the planet. The photographs, along with the hundreds of spectra and temperature measurements, were recorded and transmitted to earth in simultaneous real-time operation.

Mariner 6's mission was to cross the equatorial zone while the instruments mounted on its movable-scan platform examined specific regions of Mars. Three separate scans were executed perfectly by this platform, and an occultation experiment was performed as the spacecraft passed behind the planet where its radio signal was lost. These provided measurements of the Martian surface pressure at the spacecraft's points of entry and exit (where the radio signal was reacquired).

In 3 days of photography, Mariner 7 sent back 90 far-encounter photographs of higher quality than those obtained by the Mariner

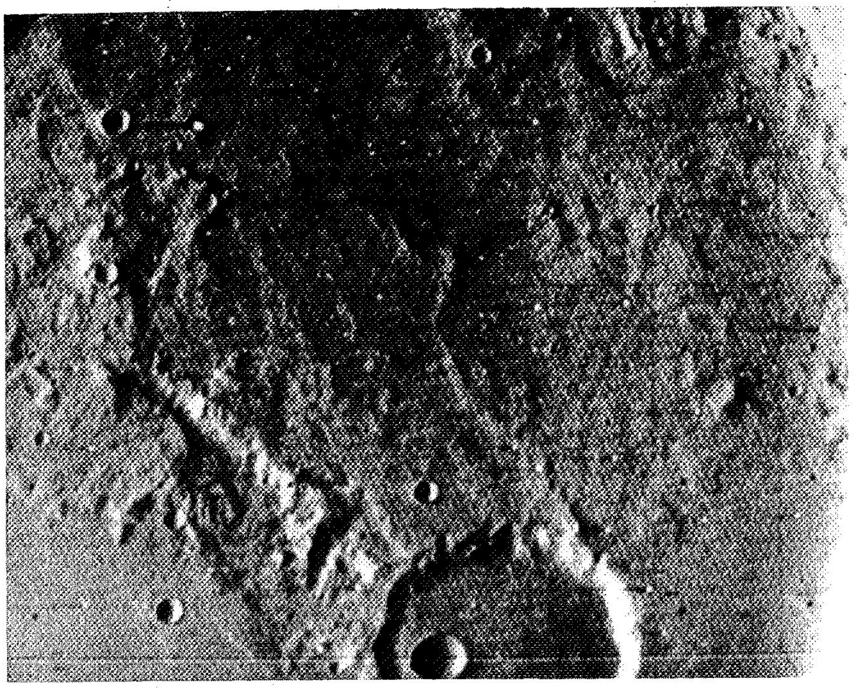


Figure 2–12. Mars from 2,150 miles away.

6 spacecraft (fig. 2–13). Its near encounter sequence (similar to that of Mariner 6 except that the spacecraft passed over the southern polar region on August 5) also supplied about 25 overlapping wide and narrow angle closeup pictures and spectral data from the other science instruments. The South Polar Cap, which Mariner 7 passed over on August 5, like iced surfaces on earth, seemed white in contrast to surrounding land surfaces and was heavily cratered as were other areas of Mars. The ice cap is probably made up of solid carbon dioxide with little, if any, water ice present. After passing over and photographing the South Pole, Mariner 7 entered the night region of the planet and its occultation zone.

A preliminary analysis of the data supplied by both spacecraft does not encourage the belief that life exists on Mars; if it does, it must be microbial. As determined by earth-based experiments and confirmed by Mariners 6 and 7, there is water vapor in the atmosphere but not enough to provide liquid water on the surface. The photographs reveal three distinct types of Martian surface: a chaotic terrain with features such as upheavals and ridges, a cratered terrain similar to the type shown by Mariner 4 in 1965, and a featureless terrain represented by the area Hellas.

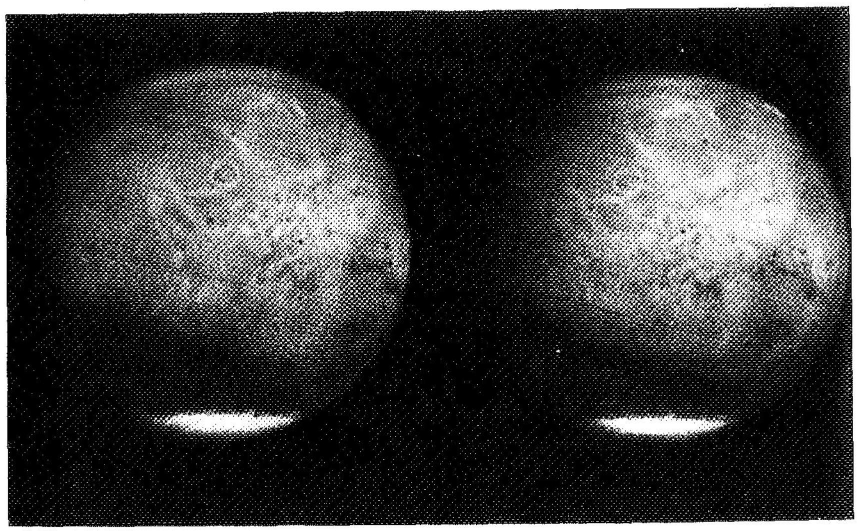


Figure 2–13. Mars seen from 293,200 miles away by Mariner 7.

Mariner Mars 1971

NASA's Mariner Mars 1971 program (Mariners H and I) was proceeding on schedule without major problems. It will use, when possible, Mariner Mars 1969 hardware. Detailed spacecraft system design and mission operations system functional design were finished in September. In October, the mission operations-tracking data system integration functional design was completed, as was the spacecraft Atlas/Centaur launch vehicle interface design.

The spare spacecraft from the Mariner Mars 1969 project was received for the Mariner Mars 1971 project. The spacecraft was disassembled, inspected, and was being modified to become the second of the two Mariner 1971 class.

Viking

In September, scientific investigators reviewed the results of the Mariner 6 and 7 Mars flybys. Following the review, the Lunar and Planetary Missions Board unanimously endorsed the Viking program as planned. The Viking project (*21st Semiannual Report*, p. 61) calls for the launching of two automated spacecraft during 1975, each consisting of a soft lander of the Surveyor class and an orbiter of the Mariner type. They will collect additional data on Mars, with particular attention to the question of life on its surface.

In answer to a NASA announcement, over 300 scientists from around the world submitted 165 proposals for scientific investigations. In December, 62 of the proposals were evaluated as ready to participate in the project, but only 25 could be accommodated in the payloads. The principal investigations to be performed during this Martian exploration will be imagery, and temperature and water mapping from the orbiter; and atmospheric composition, imagery, seismometry, organic analysis, meteorology, and a direct search for life from the lander. Major responsibilities for the program were assigned as follows: overall project management, Langley Research Center; orbiter system and tracking and data acquisition, Jet Propulsion Laboratory; lander system, Martin Marietta Corp. (Denver); and the Titan III/Centaur launch vehicle, Lewis Research Center. NASA also reached an agreement with the Atomic Energy Commission to furnish nuclear power sources for the lander.

In addition, the basic configurations for orbiter and lander were established, preliminary design begun for all system elements, and work initiated on critical long lead items such as science instruments and radar and propulsion subsystems for lander.

Pioneer

The first series of Pioneer spacecraft (nos. 6 through 9)—launched into solar orbits 1965–68—were still measuring solar wind flow, magnetic fields, and electron densities, as well as observing energy spectra fluxes and the direction of galactic cosmic rays. They make up a network of deep space weather stations. (Pioneer E, or Pioneer 10, the last in this series of spacecraft, was lost during launch in August because the launch vehicle malfunctioned.)

During November and December, Pioneer 6, which has operated longer in interplanetary space than any other spacecraft, and Pioneer 7 reached orbital positions to enable their radios signals to be received simultaneously by one earth-based antenna. In addition, the two detected the flow of the sun's energetic particles in sequence.

In the second series, Pioneers F and G (11 and 12 when successfully launched) were scheduled to be orbited in 1972 and 1973 for exploring interplanetary space, including the asteroid belt and the environment and atmosphere of Jupiter. The spacecraft of the type launched in earlier missions will be modified to compensate for the lessening of solar radiation and the more demanding communica-

tions and thermal conditions. Radioisotope Thermoelectric Generators will provide their electric power (p. 82). Negotiations for the spacecraft and scientific instruments were completed and its design work begun.

Project Helios

NASA and the Federal Republic of Germany will cooperate in the Helios project to send two probes to investigate interplanetary properties and processes in the direction of and close to the sun. *(21st Semiannual Report,* p. 62.) The spacecraft will be developed in West Germany. Three of the 10 scientific instruments, the launch vehicles, and tracking and data acquisition support will be provided by NASA.

The first project working group meeting was held in Bonn during September, at which time spacecraft specifications, launch vehicle characteristics, and other technical details of the mission were reviewed. Also, basic project organizations were set up, a training program for the Germans initiated, and the design of the scientific instruments begun. A first launch was planned for 1974.

ADVANCED STUDIES and TECHNOLOGY

Studies were made of a wide spectrum of future missions identified by NASA's Planetary Exploration Planning Panel. Conclusions drawn from the studies were that—

- Multiple, simultaneous probes from one spacecraft, launched by a Delta class vehicle, could carry out a specific investigation of the atmosphere of Venus.

- The basic spacecraft developed for the planetary "Grand Tour" missions would be able to orbit Jupiter or Saturn.

- A solar-electric spacecraft might be flown through the asteroid belt in 1975, and a multimission approach using this type of spacecraft would be feasible for either an asteroid belt survey or a Jupiter flyby.

- Low thrust, electric or nuclear-electric propulsion for spacecraft—reducing flight time while increasing the payload—could make comet rendezvous missions possible during 1975–95. Typical missions launched in 1977 to explore comets might be: a ballistic, Jupiter-gravity-assist rendezvous with Halley's comet; a ballistic, three-impluse rendezvous with the comet Enke; and a ballistic, Jupiter-gravity-assist rendezvous with the comet D'Arrest.

For the prolonged, radioisotope-powered planetary "Grand Tours" the most critical requirements are equipment to operate reliably for 9 years, to locate and replace failed parts when malfunctions occur, and to keep earth informed of the operational condition of a spacecraft during a three billion-mile flight.

To meet these stringent requirements, several concepts for spacecraft subsystems were being prepared for feasibility demonstrations. They included a self-test and repair spacecraft computer able to diagnose failures and switch in redundant parts without ground assistance; a flight telemetry subsystem that can adapt its operation to changing conditions in the spacecraft as they occur so as to send back the most useful data; and a new single channel command system of higher reliability with reduced acquisition time.

BIOSCIENCE PROGRAMS

Biosatellites

Biosatellite 3, carrying a 14-pound pigtailed monkey, was recovered July 7 after 8½ days in orbit (fig. 2–14). During this very complex biological experiment all systems functioned satisfactorily and valuable physiological data were obtained from the spacecraft's instruments. (*21st Semiannual Report,* p. 63.) A blood pressure increase in the large veins and auricles of the monkey's heart—apparent during the period of weightlessness—resulted in reflex mechanisms causing the body to discard water. This resulted in deterioration of the animal's health and necessitated recovery of the capsule and the monkey early in the mission, originally planned for 30 days. Although recovered alive, the animal died about 12 hours later.

Data from the Biosatellite 3 experiments were being analyzed further. The spacecraft and its sophisticated experiments (for example, atmosphere and environment controls, telemetry data acquisition systems, bioinstrumentation systems, catheterization procedures, and the automated urine analysis system) made significant contributions to the state of the art. Practical applications of the Biosatellite spacecraft and experiment equipment were being developed; they may have benefits in the public health area.

Exobiology

A primary objective of the Viking Mars lander mission is to detect and study extraterrestrial life and life re-

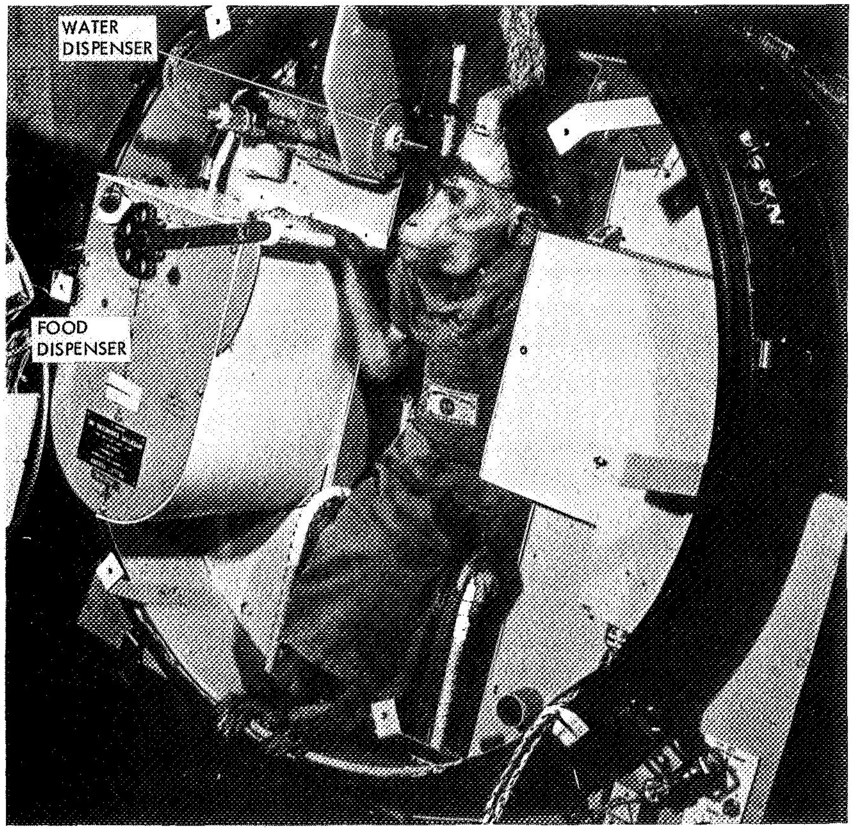


Figure 2–14. Monkey in test capsule.

lated molecules (p. 58). The responsibilities of the two groups of scientific advisors organized to support this mission—a life detection team made up of five exobiologists and a molecular analysis team also composed principally of exobiologists (organic chemists), were detailed in the *21st Semiannual Report* (p. 65).

In the course of this mission, scientists will also look for water and the evidence of past life forms. If life should not be found there, Mars will not be considered scientifically less important, since the finding of evidence related to the origin of life is a basic goal of planetary exploration. Further, an absence of life would afford an opportunity for investigating planetary evolution which could be highly significant in understanding how earth evolved.

Gravitational Biology

In space flight, the principal environmental variable is a change in gravity known as *weightlessness*. Ground based research on the effects of an increase in gravity (by centrifugation) helps in the design of space experiments and aids scientists in understanding the role of gravity in living processes. Gravity is a constant characteristic of earth's environment but very little is known of its effect on man. For this reason, chronic acceleration research—increasing the gravitational field by centrifugation—allows investigators to study the influence of this change on human physiology and behavior.

For example, obesity is the most modern and prevalent of human diseases, and chronic acceleration research at the University of California (Davis) has produced evidence that a mechanism may operate during acceleration which can regulate deposits of fat in the body. It is possible that degenerative cardiovascular disease and other diseases of aging are gravity related.

Investigators at the University of Texas Southwestern Medical School (Dallas) built a small centrifuge to study the effects of increased gravity on human cells. Preliminary experiments with liver and embryonic lung cells in tissue culture chambers, exposed in this certrifuge from 50 to 600 g for up to a month, revealed no significant differences over non-accelerated control cells. The experimenters concluded that single human cells in tissue culture should be able to grow and function normally at high g levels, as did the frog eggs and other cellular systems flown on Biosatellite 2 in September 1967.

Behavioral Biology

Measuring the activity, body temperature, and urine excretion of human subjects isolated in underground bunkers, bioscientists have made noteworthy discoveries in the field of circadian rhythms. (Earlier investigations of these regular changes in physiological and behavioral functions occurring in about 24-hour cycles were described in the *16th Semiannual Report.*) The subjects were exposed to constant (natural) lighting conditions and to artificial light-dark cycles. Under constant lighting they experienced "free-running" rhythms—lasting about 24 hours but not depending on the external environment. Also, differences in their natural circadian rhythm periods were demonstrated. For early risers the period lasted less than 24 hours; for late risers longer than a day. The differences in natural rhythm of subjects were

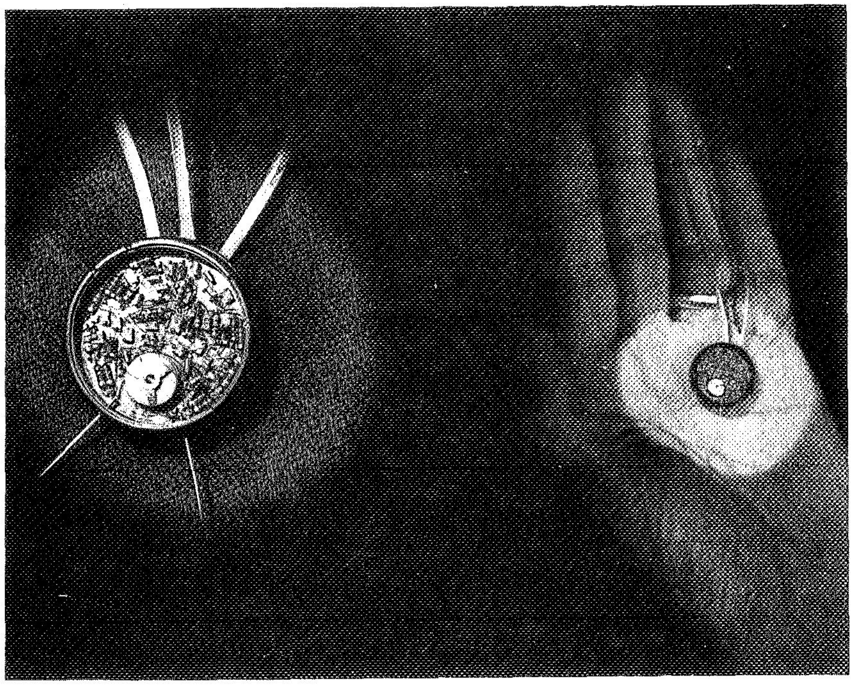


Figure 2–15. Instrument records temperature changes.

noticeably related to their ability to "follow" changes in the light-dark cycle.

In experiments shifting the dark-light schedule to simulate trancontinental aircraft flights, subjects generally readjusted to local time quicker when traveling toward the east than the west. The studies showed that an ability to readjust to an eastward to westward geographical shift was one of individual differences—that late risers would probably shift more easily to westward flight.

Physical Biology

Research on biotelemetric instruments for spaceflight use at Franklin Institute (Philadelphia) has produced a stable, accurate, long-lived implantable device to record temperature changes indicative of circadian biological clock phenomena. It will supply data for almost 2 years. (Fig. 2–15). Weighing about 3.5 grams and with a volume of 2 cc., it can detect and transmit temperature changes of 1° C. a minute from four different organs of the human body.

Other bioscientists, studying various known rhythmic fluctua-

tions in the chemistry and physiology of mammals and man, discovered that living systems also exhibit smaller, more subtle cyclic oscillations, which may be regulatory processes in the biological system. They were observed in the heart beat, respiration, temperature regulation, blood flow, and sugar levels in the blood. Similar beats, or pulses, were found in the outpouring of the endocrine system, the nervous system, water balance, weight control, and behavior responses.

SMALL and MEDIUM LAUNCH VEHICLES

In this period, NASA used Scout, Delta, Agena, and Atlas-Centaur vehicles to launch automated spacecraft (app. O).

Scout

Scout orbited ESRO 1B on October 1 and the German AZUR satellite on November 7. Improvements were being made in the Scout first stage motor (Algol 3), with completion scheduled for late in the fourth quarter of 1970.

Delta

Four launches were made by Delta. On July 26, in an attempt to launch the INTELSAT 3 F–5 communications satellite, a malfunction of the third stage kept the spacecraft from being placed into its proper orbit. Delta successfully launched OSO–6 on August 9. Later in the month, however, the Pioneer E spacecraft launch was unsuccessful due to an hydraulic failure in the first stage Thor booster, resulting in loss of control of the vehicle.

After thorough investigations of these two launch vehicle failures by review committees, Delta launches resumed with the successful orbiting of the Skynet A communications satellite November 22.

Agena

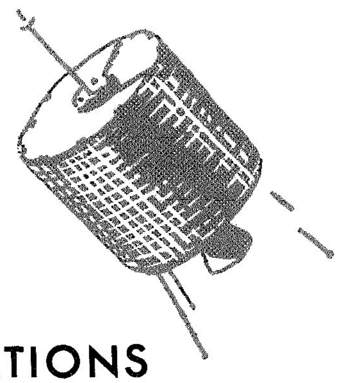
Preparations were underway for Agena launches of the Space Electric Rocket Test experiment (SERT 2) early in 1970 and Nimbus D during the second quarter of that year. The Nimbus spacecraft is the last approved mission currently scheduled for Agena.

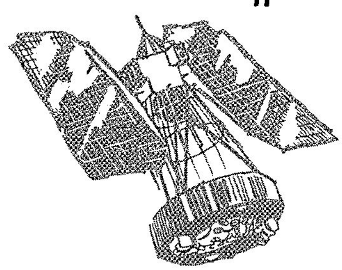
Atlas-Centaur

Atlas-Centaur orbited Applications Technology Satellite 5, August 12.

NASA and the Air Force have agreed on the integration of Titan III with the Centaur stage and the use of this vehicle to support NASA's programs. In addition, Atlas-Centaur was chosen by the Communications Satellite Corp. for NASA to use in launching the INTELSAT–4 communications satellites (on a reimbursable basis). Procurement of four of these vehicles was begun, with a first launch planned for 1971.

3 SPACE APPLICATIONS





During the period, the national network of weather satellites continued to monitor the atmosphere and to provide the world's meteorologists with daily local and global cloud cover photographs. Nimbus 3 supplied the first quantitative measurements of the atmospheric structure of the earth, spacecraft of the ATS class—being used in communications tests—also transmitted meteorological data, and the operational system of INTELSAT satellites was used increasingly for international communications.

METEOROLOGICAL SATELLITES

ESSA and TIROS

Development of TIROS-M—the prototype for a second generation of operational meteorological satellites—was completed. It was scheduled to be launched by NASA for the Environmental Science Services Administration (ESSA) in January 1970. This advanced spacecraft (fig. 3–1) will combine an Advanced Vidicon Camera System (AVCS) for global observations with an Automatic Picture Transmission (APT) System for local readout of cloud photographs. A dual-channel Scanning Radiometer (SR)

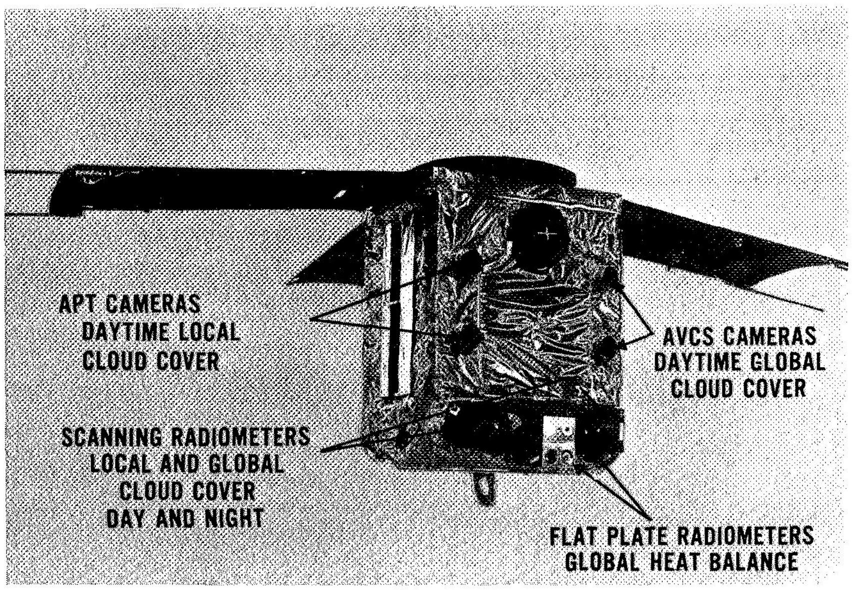


Figure 3–1. TIROS–M flight spacecraft.

System, which will afford operational night coverage for the first time, will enable the satellite to double its daily observations of earth's cloud cover. The SR will also be able to determine cloud-top height, providing a third dimension for these weather satellites.

Five satellites of the TIROS–M class were being procured to meet ESSA's operational needs in the early 1970s.

Synchronous Meteorological Satellites

NASA was also developing prototype operational Synchronous Meteorological Satellites to be orbited for ESSA early in 1972 (*21st Semiannual Report,* p. 70). The preliminary system design was established for these SMS–A and –B spacecraft. They will carry a spin-scan camera system of the type flown on the ATS satellites for daytime cloud cover observations. The design of the satellite also provides for future inclusion of improved versions of the spin-scan camera system and an infrared scanning radiometer for nighttime viewing.

Nimbus

Designed as observatories in space to test sensors and subsystems for meteorological satellites, the Nimbus spacecraft have made substantial contributions to the national operational meteo-

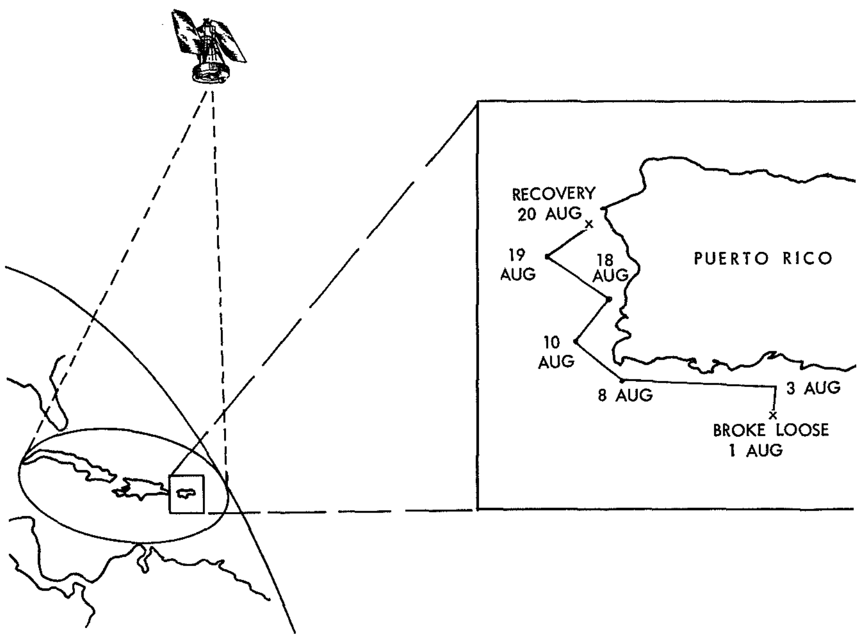


Figure 3–2. IRLS tracking helped recover a drifting buoy.

rological satellite system. They were used in the development of the AVCS and APT cameras and the High Resolution Infrared Radiometer (HRIR). Nimbus 3—launched April 14, 1969 (*21st Semiannual Report*, p. 71)—marked a breakthrough in meteorology by providing the first quantitative measurements of the world's atmosphere.

The Infrared Interferometer Spectrometer (IRIS) aboard Nimbus 3 measured terrestrial and atmospheric radiation from which scientists were able to deduce vertical temperature profiles and ozone and moisture content. (The IRIS sensor circuit failed on July 23, 1969, and this instrument no longer provides useful data.) The Satellite Infrared Spectrometer (SIRS) was measuring atmospheric energy in a carbon dioxide absorption band from which the vertical temperature distribution can be computed; it was also determining surface temperatures in cloud-free areas. Nimbus 3 also carries an HRIR sensor for day and night cloud cover observations; an Image Dissector Camera experiment to obtain high-quality pictures; an Interrogation, Recording, and Location System (IRLS, fig. 3–2) to acquire data from remote sensor platforms;

and a Monitor of Ultraviolet Solar Energy (MUSE) experiment to monitor ultraviolet solar flux.

Development and fabrication of the next Nimbus spacecraft, Nimbus D, were completed, and it was being prepared for launching in the spring of 1970. Its nine experiments will be mainly improved sensors to use infrared sounding techniques for measuring vertical profiles of temperature. These (described in the *21st Semiannual Report*) are: an improved Infrared Interferometer Spectrometer; an improved Satellite Infrared Spectrometer; an Image Dissector Camera; a High Resolution Infrared Radiometer; a Monitor of Ultraviolet Solar Energy Experiment; an Interrogation, Recording, and Location System; a Back-Scatter Ultraviolet Experiment; a Filter Wedge Spectrometer; and a Selective Chopper Radiometer.

Proposals for experiments for Nimbus E and F were evaluated. Emphasis will be placed on atmospheric measurements in the presence of clouds by microwave soundings and the use of advanced infrared sensors. The flight payload was selected for Nimbus E, and a tentative selection of experiment for Nimbus F was made. Launches were planned for 1972–73.

Meteorological Sounding Rockets

Meteorological sounding rockets were used to obtain data on the structure and characteristics of the atmosphere at heights from 20 to 60 miles—regions generally inaccessible to satellite sensors or the instruments carried by sounding balloons.

Research Rockets.—Research sounding rockets used acoustic grenades, pitot-static tubes, and light-reflecting or luminous vapor trails to provide information on atmospheric wind, temperature, and density; they used instruments employing a chemiluminescent reaction to determine vertical ozone distribution. One pitot tube and two vapor trail releases were flown from Wallops Station, Va., to transmit data on temperature and the vertical structure of the wind. However, bad weather forced postponement of 17 other flights from Fort Churchill, Canada, and Wallops Station, which were planned to explore day-to-night ozone variation, diurnal variation of winds, temperature structure and gravity waves, as well as atmospheric energy changes. They were rescheduled for early in 1970.

Rocket System.—In the NASA-Army program to develop an efficient, low-cost intermediate rocket motor for routine probings up to 45 miles, four research and development rockets underwent

successful flight tests. They returned useful data and represent noteworthy progress in the research on an inexpensive operational meteorological sounding rocket system.

Field Experiment Support.—Seventy sounding rockets were flown from Wallops Station—in conjunction with others launched from Argentina, Brazil, and Spain—to provide research and development data in an international cooperative program. During October, representatives of the space agencies of Argentina and Brazil met with NASA representatives, and reaffirmed the intention of both countries to add another launch site as soon as practicable. These two nations participate with the United States in the experimental inter-American meteorological rocket network, EXAMETNET.

APPLICATIONS TECHNOLOGY SATELLITES

The cameras of Applications Technology Satellites 1 and 3 were proving to meteorologists their value as continuous observers of earth's cloud cover. The spacecraft (orbited in 1966 and 1967) transmitted photographs of the viewable disk of the earth as often as every 20 minutes, and were thus able to supply data on the formation, growth, and decay of clouds associated with thunderstorms and tornadoes. This data, on which forecasts might be based was also furnished to ESSA, the Department of Defense, and the Federal Aviation Administration (fig. 3–3).

In addition, ATS–3 was used in radio propagation studies with a German research ship and by British ground stations in aircraft communications tests. The Japanese conducted meteorological and communications experiments with ATS–1.

After NASA has completed its program of technical experiments with these satellites, they will be made available (during their operating lifetime) to users of future operational systems for experimentation. Users could be other Government agencies, educational institutions, or private concerns willing to bear the costs of ground facilities and to provide message content. For example, NASA has received a proposal from the Governor of Alaska for an experiment to improve communications in his State by using either ATS–1 or ATS–3. The Governor proposed that instructional and other public programs be telecast from Fairbanks to three relatively heavily populated areas, and that voice communications be provided to remote areas. Alaska has begun planning, designing, and site selection for this system.

Applications Technology Satellite 5 (ATS–E)—orbited in Au-

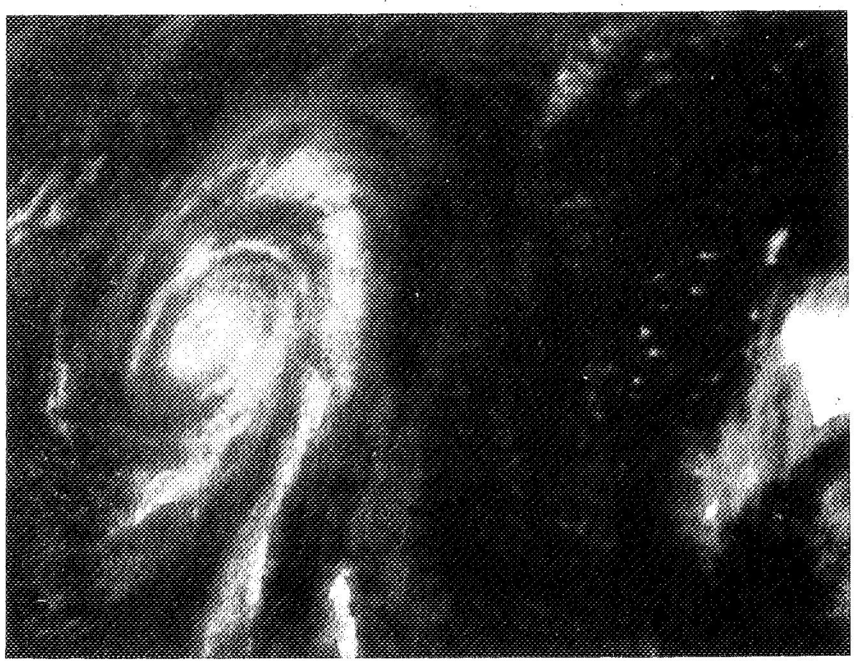


Figure 3–3. Hurricane Camille photographed by ATS–3.

gust—malfunctioned shortly after launch, but more than half of its experiments were providing useful data, including the L-band aeronautical communications and navigation experiment and the wave propagation experiment. The spacecraft, by means of the IRLS carried by Nimbus 3, helped track a free-drifting buoy (fig. 3–2).

The launches of ATS–F and ATS–G, originally scheduled for 1972 and 1974, were postponed until 1973 and 1975. Preliminary designs were completed by the contractors, and spacecraft and integration contractors were being selected. About 20 experiments were chosen for ATS–F, and almost 60 proposals for ATS–G experiments were received. Also, a memorandum of understanding was signed between NASA and the Department of Atomic Energy of India which would make ATS–F available to India (on a limited basis) for a year of experimental instructional telecasts direct to community receivers.

COMMUNICATIONS SATELLITES

INTELSAT

In July, NASA launched the INTELSAT–3 F–5 communications

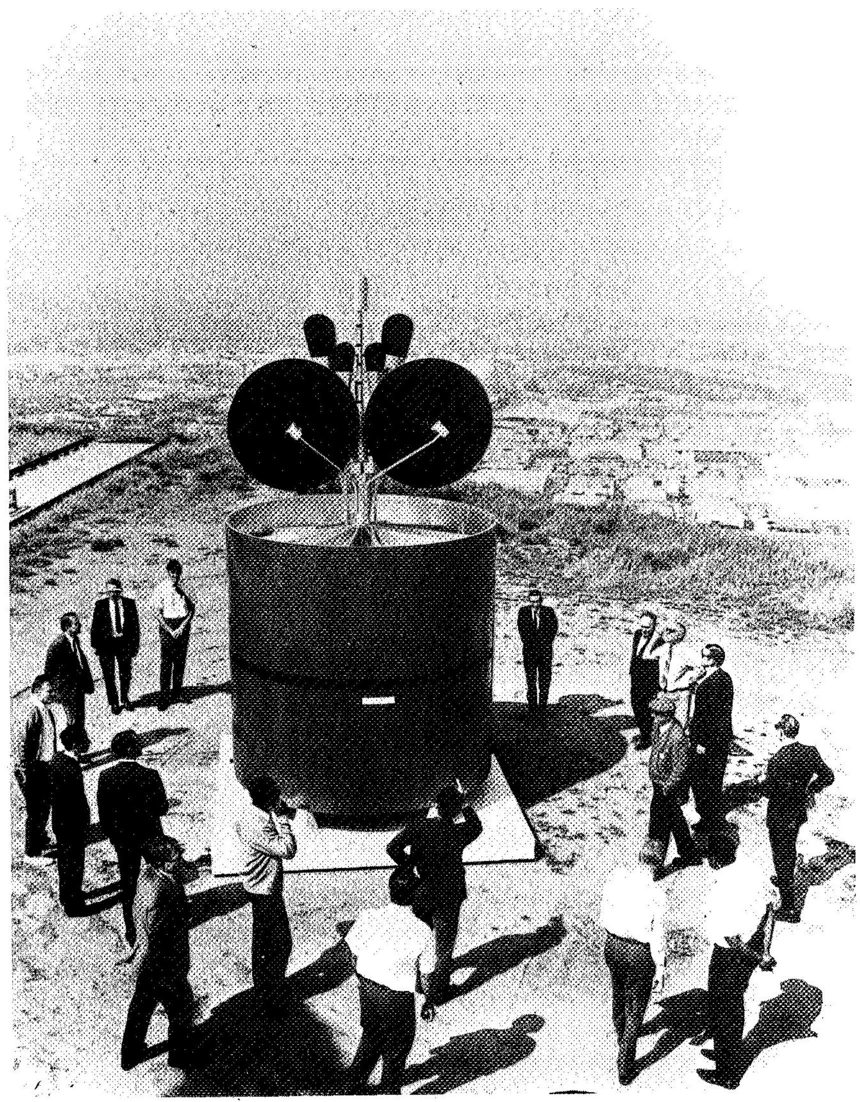


Figure 3–4. INTELSAT–4.

satellite for ComSat, on a reimbursable basis. However, a launch vehicle malfunction kept INTELSAT–3 F–5 from achieving a proper transfer orbit. INTELSAT–3 F–3 (launched in February) placed in service over the Pacific, was repositioned over the Indian Ocean to begin service July 1. INTELSAT–3 F–4 (launched in May) was in service over the Pacific Ocean. A malfunction of the mechanically despun antenna of INTELSAT–3 F–2—positioned

over the Atlantic since December 1968—caused the satellite to stop operating in July and required the reactivation of Early Bird, INTELSAT–1, to help provide communications services for the North Atlantic region and Europe. When the spacecraft began operating again in August, Early Bird was turned off.

Three more INTELSAT–3 satellites were scheduled for 1970 launches, followed by the orbiting of the first of a new generation of operational communications satellite, INTELSAT–4, in 1971.

INTELSAT–4 will provide up to 9,000 two-way voice circuits or 12 TV channels for 7 years. (INTELSAT–3 provided 1,200 voice circuits during a 5-year lifetime.) ComSat selected the Atlas-Centaur vehicle to launch the INTELSAT–4, and NASA and ComSat have agreed on the launch services and the purchase of the vehicles. This satellite will weigh about 3,080 pounds at launch and be almost 18 feet high and about 8 feet in diameter (fig. 3–4). NASA will also serve as consultant to ComSat, on a reimbursable basis, and as adviser to the Federal Communications Commission.

GEODETIC SATELLITES

GEOS

The instruments aboard GEOS–1 (launched in 1965) measured time variations in the earth and its gravity field and provided an accurate global description and a direct comparison of geodetic systems. GEOS–2 transmitted additional data of the type being secured by GEOS–1 and aided in comparing and calibrating laser tracking equipment of NASA and the Smithsonian Astrophysical Observatory (Mount Hopkins, Ariz.). Orbited in 1968, the second GEOS satellite continued to support Air Force camera teams in geodetic observations of South America and to assist in the calibration of selected C-band radar systems in order to determine whether data acquired by them might be used to position geodetic stations and measure intersite distances (*21st Semiannual Report*, p. 79).

The next spacecraft of this type—GEOS–C planned for a 1972 launching—will be able to measure mean sea level and the dynamic variations of the ocean surface, as well as provide other data needed to describe the earth's gravity field.

PAGEOS

The passive spherical satellite PAGEOS–1, launched in 1966, was still supplying geodetic data.

NAVIGATION and TRAFFIC CONTROL SATELLITES

NASA and the FAA continued cooperative work on developing a system description of a preoperational UHF navigation-traffic control satellite experiment for the North Atlantic (*21st Semiannual Report,* p. 78). NASA has also discussed cooperative testing of this satellite experiment with the European Space Research Organization, ESRO (p. 141).

EARTH RESOURCES SURVEY

Preliminary analyses were completed and the contractors selected for system definition and design of the first two Earth Resources Technology Satellites (ERTS–A and ERTS–B). Other contractors were chosen to study spacecraft definition and the data management system. The design specifications for the satellites were reviewed and approved by the Earth Resources Survey Program Review Committee made up of representatives of NASA and the Departments of Interior, Agriculture, Commerce, and Navy (*21st Semiannual Report,* p. 80).

The ERTS spacecraft—scheduled for 1972–73 launches—will circle the earth at an altitude of 570 miles in a nearly polar orbit, providing repeated earth coverage every 17 days. Their objectives will be to help determine if an operational earth resources survey system would be useful and efficient; flight-test sensors; and supply earth resources survey research data to users of the satellites.

Examples of the "products" to be developed by users of ERTS–A and ERTS–B data would be photo images at about a 1:1,000,000 scale, as well as photo images of large geological features, and land-use, coastal area, and snow cover plots. The photographs and data will be supplied by the high-resolution TV cameras and multispectral point scanners carried by the satellites. NASA, its contractors, and the other Government agencies cooperating in this program were developing methods to handle this information.

Aircraft Program

In support of future earth resources survey satellite programs, aircraft flights were made to obtain experimental remote sensor data. The flights were made over the Atlantic to obtain information on sea state and sea surface temperatures and over test sites in the United States. Other areas overflown were in Mexico (*21st Semiannual Report*), Brazil, and other parts of South America.

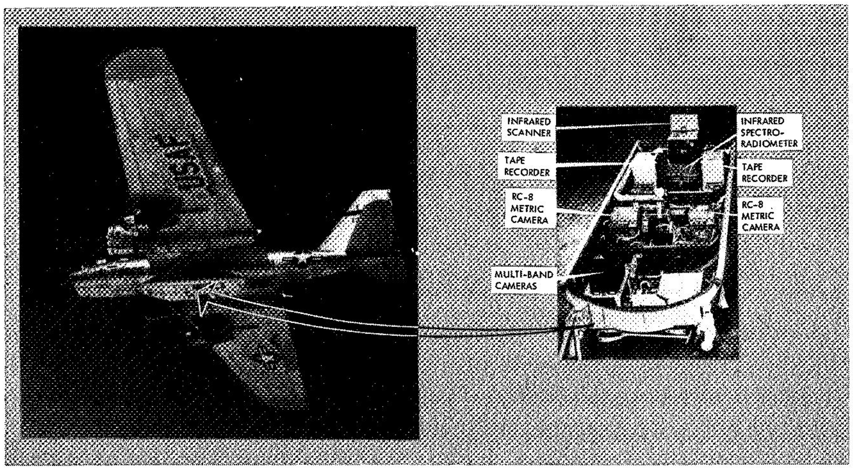


Figure 3–5. RB–57 aircraft and instrument pallet.

Data in support of the International Biological Program were obtained from flights over Argentina.

The ability of aircraft equipped with remote sensors to assess damage and help planners during emergencies was illustrated in the aftermath of Hurricane Camille (fig. 3–3, p. 72) which struck in the Gulf Coast area in August. NASA planes flew over this area the day after the storm to take color photographs which clearly revealed the nature and extent of damage to natural and manmade features. This information was forwarded to the Corps of Engineers, the Office of Emergency Planning, and the Small Business Administration for use in recovery operations.

During the past 6 months the payloads of these aircraft were increased. For example—as recommended by the National Academy of Sciences—NASA arranged with the Air Force for part-time use of an RB–57 jet reconnaissance aircraft (fig. 3–5). Sensors for earth resources surveys were mounted on a pallet for easy attachment to this airplane, which has made a number of flights.

Also, a C–130B (fig. 3–6) was obtained to replace an earlier cargo type aircraft used in such surveys. In addition to handling a considerably larger payload, the C–130B can carry more observers and perform at higher altitudes and greater ranges. Further, its facilities for loading and off-loading surface vehicles allow the inclusion of a specially equipped mobile ground-truth vehicle as part of the sensor verification equipment. The vehicle provides ground instrumentation at test sites which lack the field equipment

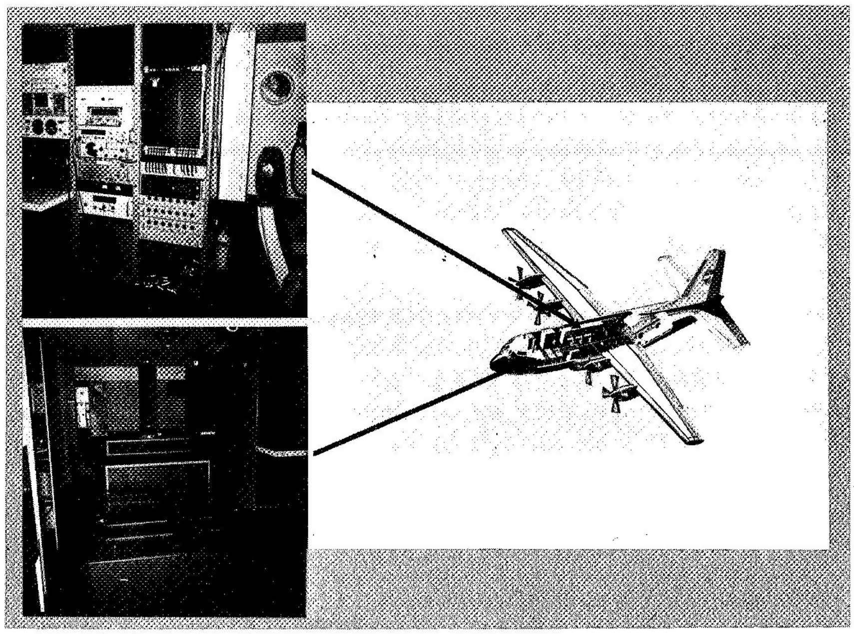


Figure 3–6. C–130B used for earth resources surveys.

to collect the correlative data required for proper sensor evaluation. The 24-channel multispectral research scanner being developed for NASA will also be installed in this aircraft.

Supporting Research and Technology

The SO–65 multispectral camera experiment, conducted during the Apollo 9 mission in March 1969, supplied the first space-acquired pictures of the specific type needed for earth resources surveys. Primary purpose of this experiment was to verify the choice of spectral bands for the ERTS television cameras. The green band was found to be suitable for measuring water penetration, red and near-infrared bands for crop and feature identifications, and the near-infrared band for plant stress determination and identification of surface water.

Also, a first attempt was made during the Apollo 9 mission to evaluate the use of simultaneous spacecraft and aircraft imagery and sequential imagery to inventory natural resources. A combination of the photographs taken from the spacecraft and from high- and low-altitude aircraft revealed tonal signatures of agricultural fields well preserved in the small-scale spacecraft imagery. The

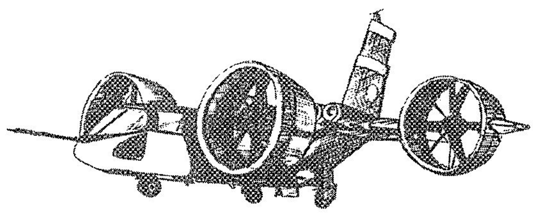
tonal signatures, combined with sequential coverage, established the feasibility of constructing calendars for identifying crops, estimating their yield, and determining their vigor.

The Forest Service used a similar technique to develop an accurate, time-saving method for inventorying forest timber volume. In this procedure, timber volume was calculated by five stages of sampling and calculations based on space-aircraft imagery, along with a limited (but detailed) tree volume measurement on the ground.

In addition, at Purdue University digitized data obtained from sophisticated multispectral sensors were used as an aid in the automatic classification of soils and to help geologists classify terrain. Elsewhere work continued on developing other sensors sensitive, accurate, and reliable enough to be flown aboard spacecraft for remote surveys of air pollutants.

4

ADVANCED RESEARCH AND TECHNOLOGY



The Office of Advanced Research and Technology continued to make progress in the many activities for which it is responsible. Its operations, which serve to establish the technical base for future aeronautics and space developments and missions, to evaluate the potential of new technology, and to support the development and operation of specific new vehicles, include a wide variety of projects. Some of them are described in the following section.

SPACE POWER TECHNOLOGY

Solar and Chemical Power

Progress continued on solar cell, battery, and fuel cell technology. Work on large-area (1,000 to 5,000 square foot) solar cell arrays made consistent advances during the years 1965–69, and in this period important steps were taken toward the goal of technology readiness of a 250-square foot module (2.5 KW) rollup array with a power to weight ratio of 30 w/lb.

Experimental data were obtained on the degradation mechanisms for thin film cadmium sulfide solar cells. These cells may significantly reduce power system costs if key problems of degradation and low efficiency can be solved.

Work on rechargeable silver zinc batteries also made excellent progress, and research continued on materials and components needed to extend fuel cell life beyond the present 2,000 to 3,000

hours. The third-electrode nickel cadmium battery, a product of the NASA research and advanced technology program (*21st Semiannual Report*, p. 83), completed a full year of operation on the OAO–2 satellite.

Nuclear Electric Power Research and Technology

Research continued in several experimental and analytical programs concerned with isotope and reactor space dynamic systems.

Rankine Turbogenerator Technology.—The current objective of this program is to develop component technology suitable for the eventual development of a 300 KWE reactor power system. The three-stage potassium turbine (*21st Semiannual Report*, p. 84) accumulated 1,700 additional hours of experimental erosion data in a planned 5,000 hour test. In addition, life testing of a full-scale electromagnetic, potassium boiler feed pump was started, and 3,000 test hours were completed. Finally, a three-loop experimental boiler tube test facility neared completion and testing of single full-scale tubes is expected to begin next year.

Thermionic Conversion Technology.—The thermionic diode kinetics experiment at JPL has now operated successfully for several thousand hours. This facility, whose primary purpose is the study of fast (neutron spectrum) thermionic reactor system dynamics and control, utilizes four high performance cylindrical diodes cooled by flowing liquid metal to simulate an actual nuclear reactor application. (Fig. 4–1.) The testing to date has verified the existence of a "thermionic burnout" condition previously postulated only analytically; achieved stable startup of series-coupled diodes including the effects of reactor dynamic feedback factors, and showed satisfactory recovery from abrupt transient load and reactivity perturbations utilizing constant voltage output control.

Irradiated thermionic fuel capsules from the NASA Plum Brook test reactor were examined and showed some swelling of uranium dioxide fuel specimens and good dimensional stability of "porous" uranium carbide specimens. Testing of the carbide specimens was resumed, and fuel burnups equivalent to more than 20,000 hours of operation (of a 100 kilowatt power system) were achieved.

An "uninsulated" externally fueled protype diode was in the final fabrication stage before testing, and an unfueled diode of similar design began what is expected to be extended out-of-pile testing.

Phase I detailed design studies were completed on a typical 300

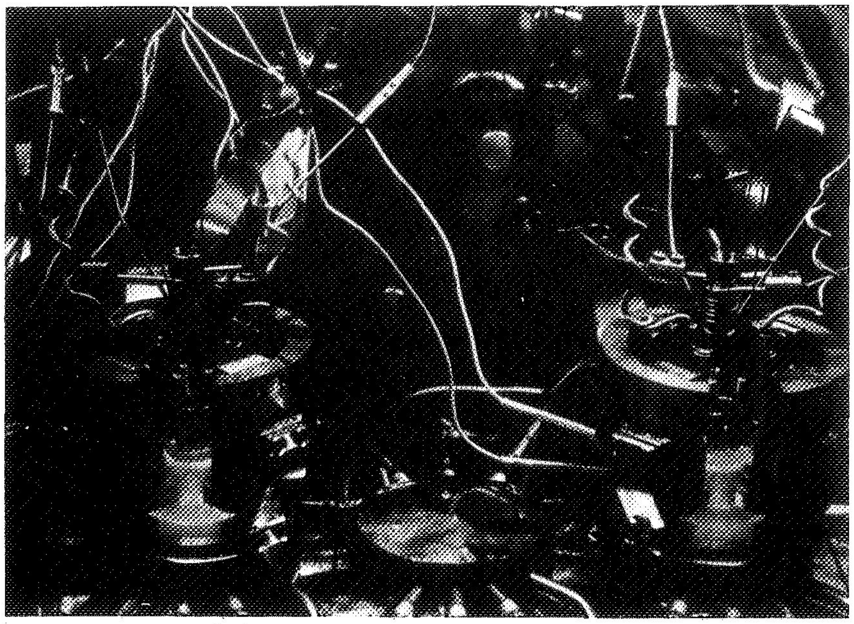


Figure 4–1. Thermionic diodes operating at 1,800° C.

kilowatt thermionic reactor power plant for unmanned electrical propulsion applications. The total power plant/propulsion unit would weigh approximately 18,000 pounds and would be configured for launch by a Titan III-class booster. Such a system may be suitable for a Jupiter orbiter mission.

Brayton Cycle Technology.—The objective of this program is to investigate the performance and life limits of the Brayton cycle for use with either isotope or reactor heat sources. Initially, the program is aimed at developing the technology for a 2–10 KWE space power system which would use an isotope heat source.

A combined turboalternator-compressor unit, mounted on gas bearings, has now been operated for 1,014 hours. Startup and shutdown characteristics were determined and performance demonstrated. Other individual components of a power conversion system were also placed in test.

The first test of a complete 2–10 KWE power conversion system designed for eventual use with an isotope heat source giving a turbine inlet temperature of 1,600° F. was initiated in the Plum Brook Space Power Facility. In the tests, which used an electrical heat source, 592 hours of running were achieved and a conversion

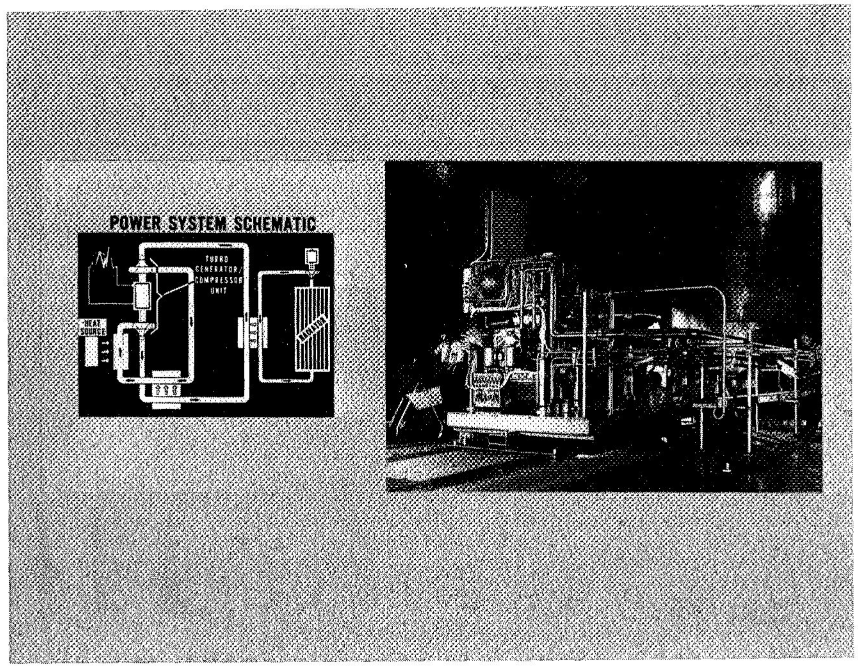


Figure 4–2. Brayton power system.

efficiency of 22 percent demonstrated at 1,400° F. turbine inlet temperature. (Fig. 4–2.)

Isotope Power.—The SNAP–19 radioisotope thermoelectric generator (RTG) power units on the Nimbus B2 satellite continued to supply useful power 9 months after launch. Performance data are continually being evaluated to provide a basis for design and performance prediction of RTG's for future space missions.

The SNAP–27 RTG power supply for the Apollo Lunar Surface Experiment Package (ALSEP) was placed on the moon during the Apollo 12 mission. Performance to date has been as predicted and satisfactory.

NASA selected RTG's to be the primary power source for the Pioneer F and G missions and for the Mars Lander of the Viking mission. Arrangements were made to obtain suitable power units through the AEC. Several required experiments to evaluate RTG/spacecraft interactions in these missions were identified. Programs to define and resolve RTG/spacecraft integration and operational problems and tests of RTG's for stability and long-term reliability were continued.

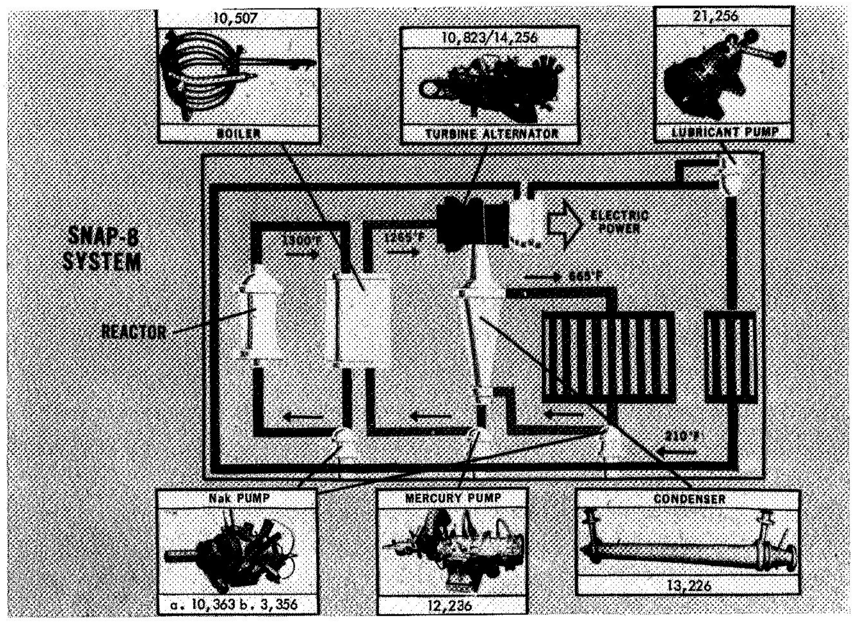


Figure 4–3. SNAP–8 system; endurance hours as of December 31, 1969.

SNAP–8 Technology Development.—The objective of the SNAP–8 program is to develop the technology for a 35–50 KWE space power system which will use a nuclear reactor as the heat source. During this period, the boiler and turbine, which in past years experienced major difficulties, successfully completed 10,000 hours of testing, and all major components of the power conversion system have now achieved a demonstrated life of 10,000 hours, with some components reaching 14,000 to 20,000 hours. (Fig. 4–3.)

An experimental program to define system startup and shutdown dynamic characteristics was completed, using a breadboarded power conversion system located at the Lewis Research Center. (Fig. 4–4.) Data essential for designing the power conversion system for testing with the reactor were obtained.

The Atomic Energy Commission terminated testing of the seconds NAP–8 reactor after 7,000 hours of power operation because the fuel element cracking observed in the test of the first reactor was also occurring in this reactor. The reactor will be opened for an examination to determine the cause of this problem.

The Electric Propulsion Program

Electric propulsion systems are of interest for difficult auxiliary

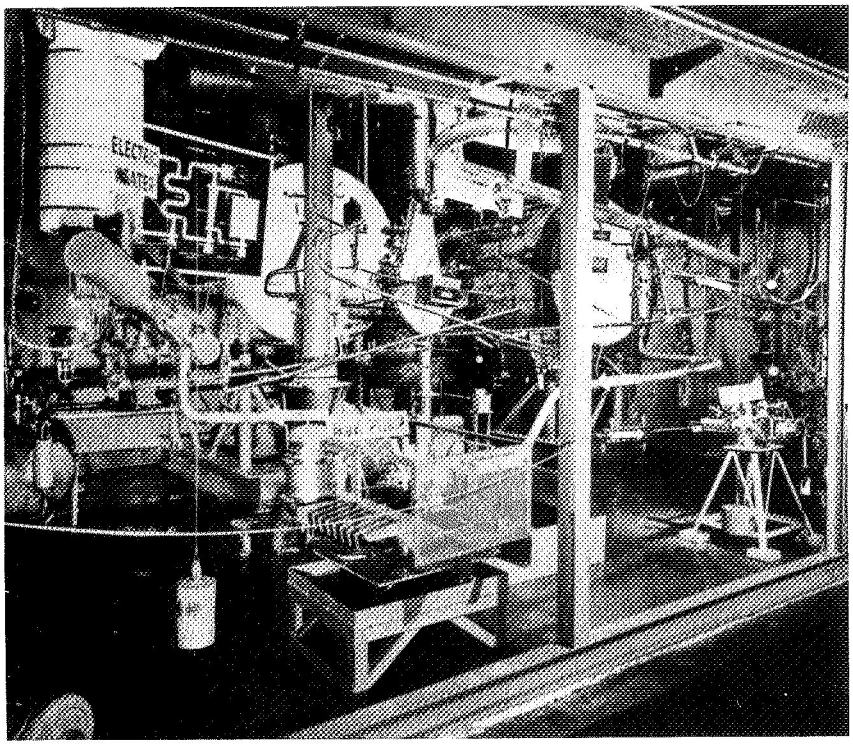


Figure 4–4. Breadboarded system startup test facility.

propulsion missions, such as long-term satellite station keeping, and for many primary propulsion applications, such as those involved in planetary exploration. The development of the technology required for such applications continued to progress.

Auxiliary Propulsion.—Cesium contact ion engine experiments were carried on ATS–V (launched August 12), but their operation will depend on whether satisfactory spacecraft performance can be achieved. These engines, designed for satellite east-west station keeping at a thrust level of about 10^{-5} lbs., were first operated on ATS–IV (*20th Semiannual Report,* p. 95). North-south station keeping requires a higher thrust level (10^{-3} lbs). The bombardment ion engine appears best suited for this role because of its economical use of electrical power, and plans were made to include an engine of this type on the ATS–F. (Fig. 4–5.)

Following the successful life tests of resistojets described in the *21st Semiannual Report* (p. 89), recent space station studies have included the use of such engines in the baseline designs. Initial

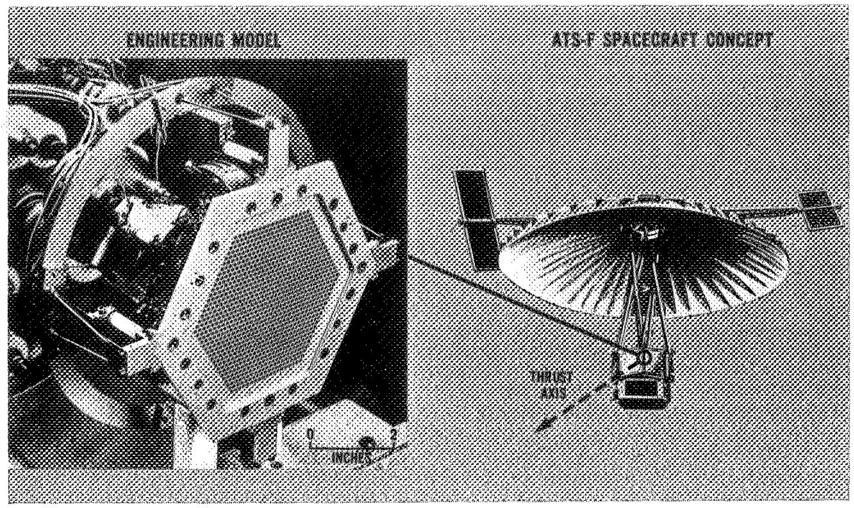


Figure 4–5. Ion engine for station keeping.

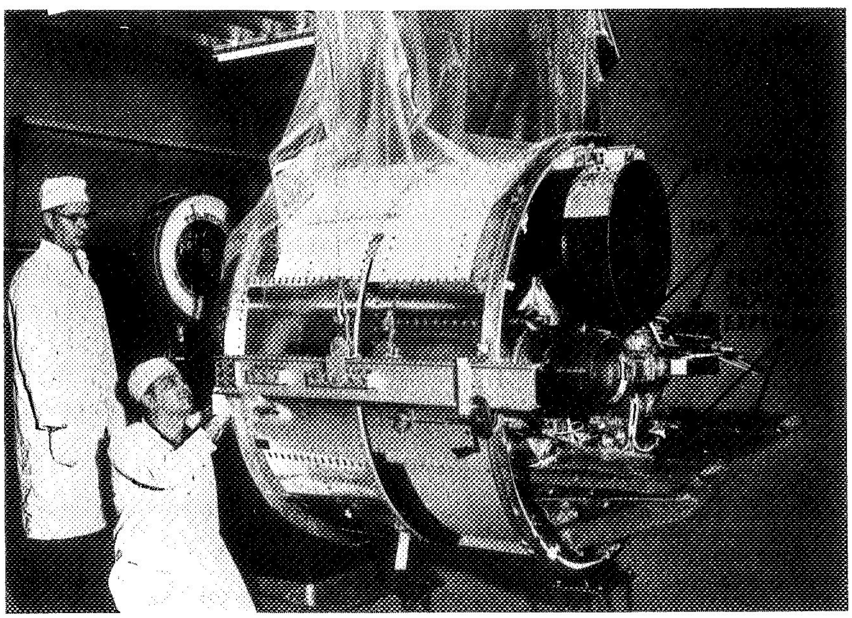


Figure 4–6. SERT II flight spacecraft.

tests of resistojets capable of operating on biowastes such as carbon dioxide, methane, urine, and water, were conducted, research was begun on thrusters, and work was started to develop the technology required for integration with life support systems.

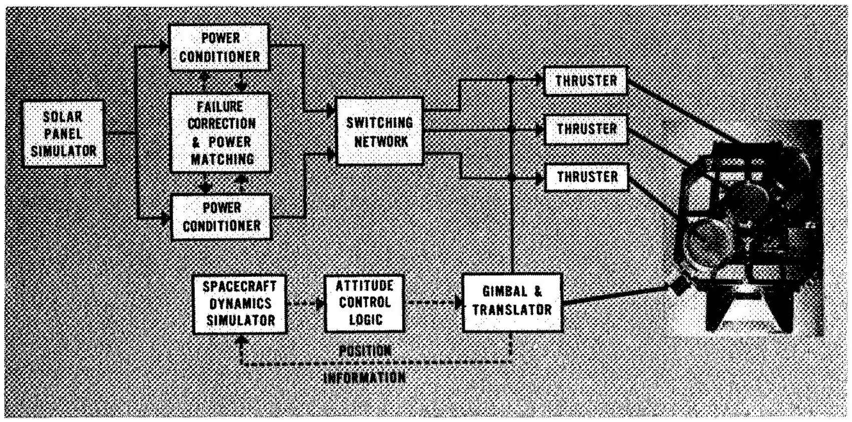


Figure 4–7. Mission simulation—automatic closed-loop operation.

Prime Propulsion.—The launch date of the SERT II orbital test was moved into the first quarter of 1970 to permit additional testing of the thruster and power conditioner. (Actual launch date was February 3, 1970.) The objectives of this flight are to verify long-term (6 months) bombardment ion thruster performance in space, and to carry out experiments aimed at assessing interactions between ion propulsion and spacecraft. (Fig. 4–6.)

The ground test program designed to prove the feasibility of solar-powered electric propulsion made progress toward realistic simulation of all required operational functions for an interplanetary mission. The hardware and various logic subsystems needed to achieve automatic closed-loop system operation were being assembled for tests expected to begin toward the end of 1970. (Fig. 4–7.) The completion of this test program and the SERT II flight tests will significantly advance electric propulsion technology based on bombardment ion engines toward mission use.

SPACE VEHICLES PROGRAM

Environmental Protection and Control

Radiation Shielding.—As a result of research on charged particle radiation shielding, the ability to calculate the effectiveness of shields against high energy protons was improved. Codes which were previously applicable for particles up to 400 MEV were extended to energies as high as 3 GEV. In addition to their value in space vehicle shielding studies, the codes will be useful for shielding calculations connected with the supersonic transport program and high energy particle accelerators.

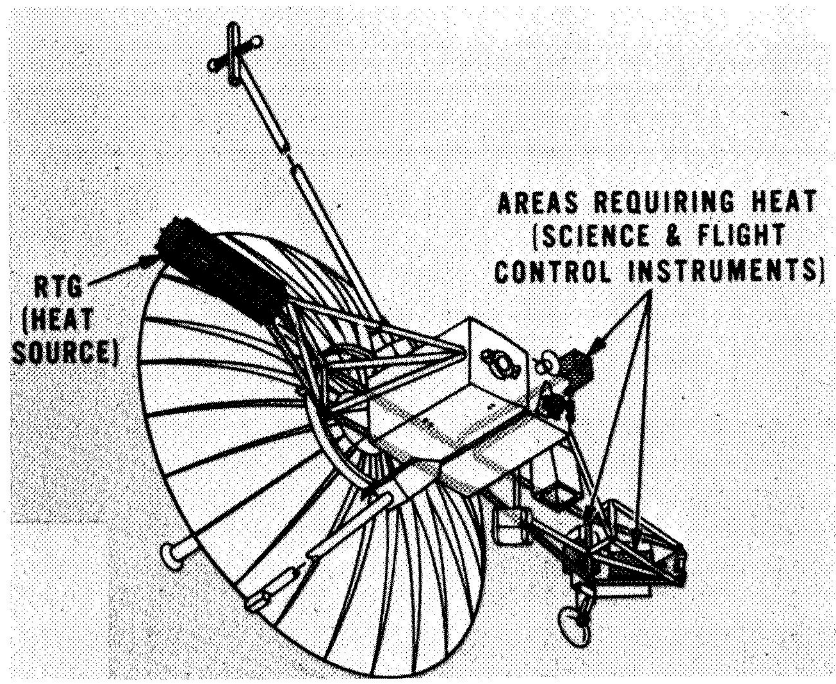


Figure 4–8. Heat pipe application in outer planet spacecraft.

Meteoroids.—The Pegasus III meteoroid detection satellite reentered the Earth's atmosphere on August 4. For about 2 weeks before reentry, a sequence of commands was carried out to ascertain the status of the various spacecraft components, and all subsystems were operating properly at the time of reentry. During the 4-year lifetime of the spacecraft no major failures were experienced.

Temperature Control.—In research on the heat pipe—one of the most useful devices to transfer heat on a spacecraft—bronze was found to be the most suitable material for heat pipes using water as the condensible fluid. When water was used in a stainless steel pipe, hydrogen, a noncondensible gas was generated causing performance to deteriorate markedly. One important possible use of the heat pipe will be in spacecraft for outer planet missions to distribute waste heat generated by RTG power sources to various components. (Fig. 4–8.)

A family of stable thermal control coating pigments, which uses powdered insulator materials rather than semiconductors or die-

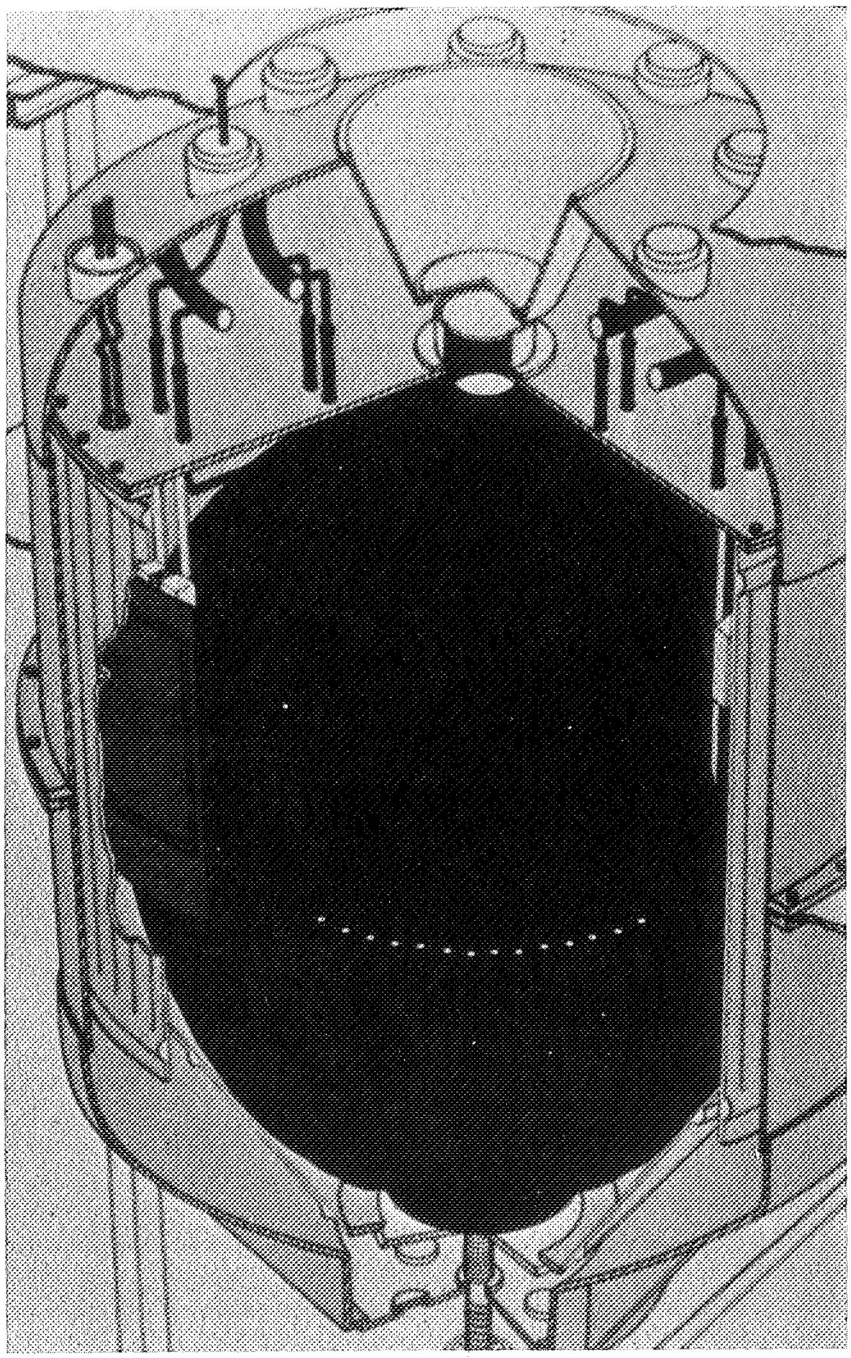


Figure 4–9. The JPL MOLSINK.

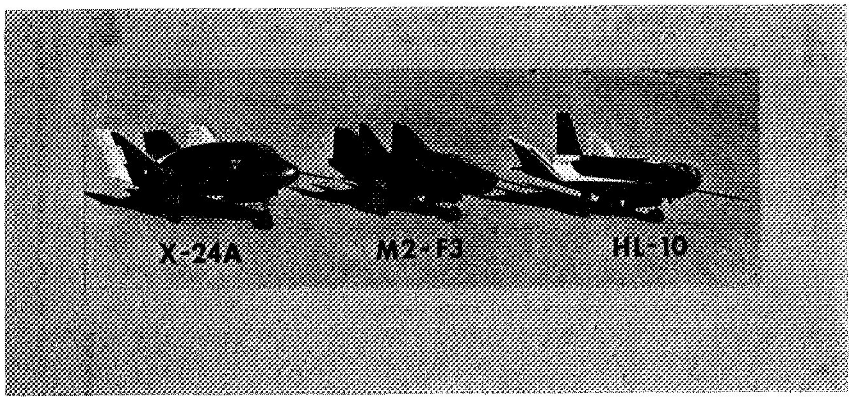


Figure 4–10. Lifting-body flight vehicles.

lectrics, was developed. The stability of the new pigments should be highly useful in applications where a higher solar absorptance is tolerable. For large spacecraft which will require low solar absorptance, zinc orthotitanate pigment formulations were nearly ready to be put into use.

Thermal/Vacuum Test Technology.—A prototype solar simulator arc was operated at power levels up to 400 KW using xenon, krypton, and argon. Spectral measurements were made and will be used as the basis for selecting the best choice for solar simulation. Results of a space flight experiment to study the phenomenon of cold welding were compared with results of tests in a conventional vacuum facility and in the JPL MOLSINK (space molecular sink simulator) facility. The tests in the MOLSINK facility produced results equivalent to space operation whereas the tests carried out in the conventional vacuum facility did not. Studies were being conducted to determine whether such testing requires a facility with the sophistication of the MOLSINK. (Fig. 4–9.)

Space Vehicle Aerothermodynamics

Lifting-Body Flight Program.—Since the last report, the HL–10 made 10 powered flights, expanding the flight envelope to near the maximum capability of the vehicle with flights at Mach 1.6 and to an altitude of 80,000 feet.

The X–24A made six glide flights to obtain basic flying qualities information before powered flight. Beginning with the next flight, which will be powered, the flight envelope will be expanded grad-

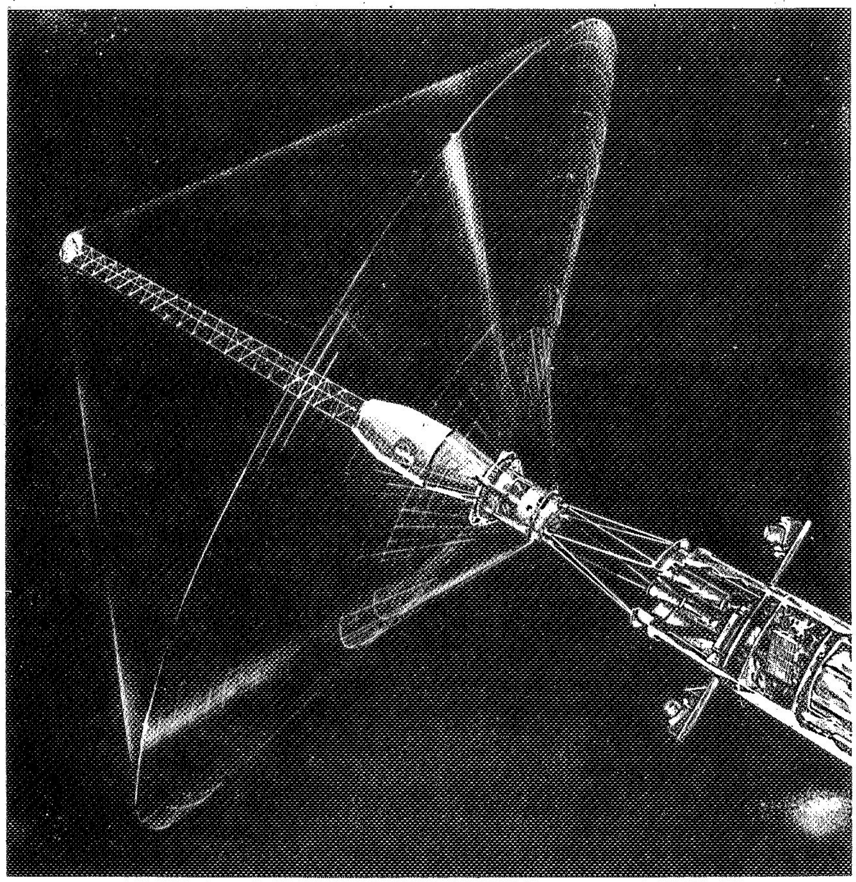


Figure 4–11. Radio telescope.

ually to near Mach 2.0 and an altitude near 100,000 feet. (Fig. 4–10.)

Advanced Decelerator Concepts.—The flight test program on supersonic parachutes suitable for use in planetary entry and landing was extended to obtain additional data. In a fourth flight, a reefed Disk-Gap-Band parachute was successfully tested at Mach 2.5. Drag and stability of the parachute were determined by onboard load sensors and motion picture cameras.

Space Vehicle Structures

Radio Telescope Technology.—A spinning small scale structural model of an orbiting radio telescope was tested in a vacuum cham-

ber. (Fig. 4–11.) The tests are part of the technology development effort for achieving a parabolic antenna 1,500 meters in diameter capable of operating in space and receiving natural radio signals in the 1 to 10 MHz range. Current research is concentrated on the solution of difficult structural and dynamic problems related to an advanced concept of a spinning antenna constructed as a parabolic net which maintains its shape by a combination of centrifugal forces and a system of filamentary stays attached to a central mast. The entire structural system is packed on drum-like devices mounted on a storage cannister. It is deployed by spinning and unreeling the antenna net with its stays and extending the central mast.

The model tests showed that the deployment can be simulated in the laboratory and that preliminary dynamic characteristics can be demonstrated.

Space Vehicle Design Criteria

Six space vehicle design criteria documents were published in this period. The new publications, prepared by technical specialists from the aerospace community and published by NASA as guides for the design of new space vehicles and for modifications in existing vehicles, are listed in Appendix N. (SP–8013, 8017, 8020, 8021, 8023, and 8029.)

Space Shuttle Technology

Preliminary investigations have been initiated to define configurations and to investigate aerodynamics, structures, materials, dynamics, and aeroelasticity characteristics. Significant results have already been obtained particularly with regard to understanding complex flows surrounding candidate configurations.

SPACECRAFT ELECTRONICS and CONTROL

Communications and Tracking

Optical Propagation Tests.—Plans were completed for two series of flight tests to determine the effect of the atmosphere on optical communication systems for space vehicles. The tests will emphasize the collection of data on laser beams projected vertically. Goddard Space Flight Center will test equipment on high altitude balloons by pointing laser beams of various wavelengths at the balloon equipment as it rises and floats. A sensor on the balloon will record variations in amplitude and coherence width, meteoro-

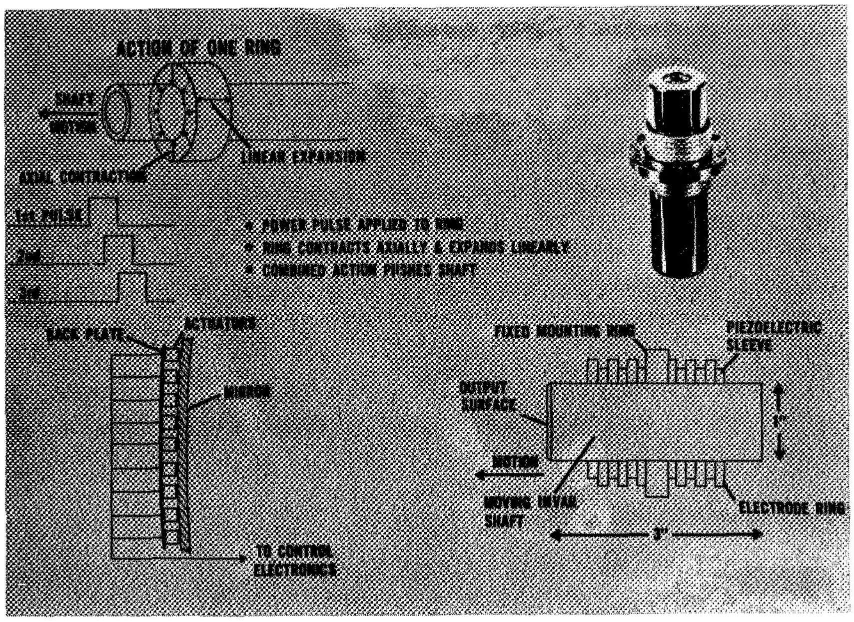


Figure 4–12. Microinch actuator.

logical data will be taken at the same time, and the two sets of data will later be correlated.

Marshall Space Flight Center will conduct propagation tests using a U–2 or similar aircraft. These tests will determine the effect of the atmosphere on propagation of laser beams at various elevation angles and meteorological conditions, including cloud cover. Lasers and communication receivers will be installed in the aircraft and on the ground.

The flight tests are two parts of a single unified program designed to achieve results for researchers in propagation effects and for engineers designing practical communication systems.

Active Optics Technology.—A microinch actuator for use in active optics systems was developed and successfully demonstrated under an Electronics Research Center contract. The actuator, which is used to change the position of the various parts of a primary mirror for a large space telescope, can achieve controlled movements as small as one ten-thousandth the diameter of a human hair. An array of such actuators can completely control a large mirror and compensate in space for changes in the gravity field, thermal effects, and structural deformations. (Fig. 4–12.)

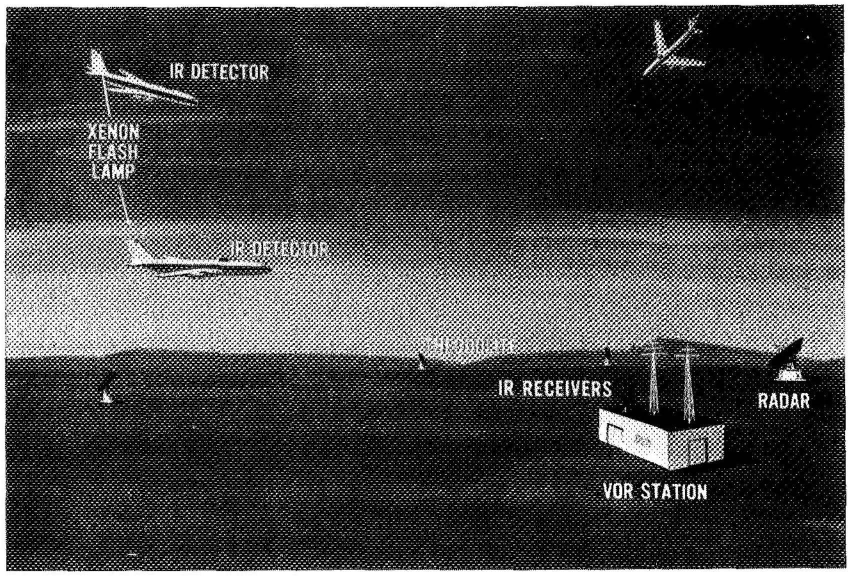


Figure 4–13. Optical PWI test concept.

Pilot Warning Indicator.—The microwave pilot warning indicator (PWI) developed at Langley Research Center was flight tested in two aircraft with satisfactory results. Primary effort will now be to make the equipment light and inexpensive enough for use by general aviation aircraft.

Optical pilot warning equipment was also being developed by the Electronics Research Center. Similar equipment, developed and funded by an electronics concern as a result of the request for quotations by the Electronics Research Center, was purchased and will be flight tested early in 1970. (Fig. 4–13.)

Spacecraft Attitude Control

The Ames Research Center has developed a new and powerful attitude control concept for large-angle satellite maneuvers required to change the pointing direction of spaceborne telescopes. The new concept (derived from Euler's theorem) permits closed loop coordinated rotation that allows any change of attitude to be carried out by a single rotation. It is insensitive to unexpected force or system performance changes and is stable under any maneuver.

Guidance and Navigation

The radiometric calibration of infrared devices used in horizon sensors and measurement equipment is limited to an accuracy of about 5 percent. Future flights will require system calibration approximately five times more accurate. The Langley Research Center researchers demonstrated the feasibility of developing a 1-percent system. A precision blackbody source was built and tested, and a design study for the complete calibration system was completed.

General Aviation Avionics

The objective of work in this area is to provide avionic system technology, development, and criteria that will enhance the safety and utility of general aviation aircraft. Simulators and flight vehicles were used to investigate new concepts in flight control, displays, and system components. Projects completed included an investigation of the effectiveness of yaw dampers during the critical phase of a final approach under turbulent conditions and an examination of the efficiency of angle of attack as a control display. In addition, various elements of a total electronics system were being developed or studied. A digitally controlled frequency synthesizer capable of time shared operation to give two Very High Frequency Omni Range (VOR) bearing inputs to a course line computer and a Morse code VOR station identification decoder were fabricated and being evaluated, and a liquid crystal chart overlay was undergoing feasibility studies.

Instrumentation

Photodetectors.—Many experiments involving detection of very low level light signals require a sensitive detector—the photomultiplier. Langley Research Center developed a system which will display in real time a color coded sensitivity map of a photodetector on a color TV receiver. Immediate observation of changes in area sensitivity make it possible to determine optimum performance conditions and to record the effects of localized fatigue of photocathodes and the time required for their recovery. This information, in turn, makes it possible to improve such photomultiplier characteristics as stability and uniformity of area sensitivity.

Irradiated Semiconductors.—Earlier Langley studies of changes in the electrical and optical properties of semiconductors (silicon and germanium) caused by controlled radiation showed that the changes were similar to those caused by chemical doping; as a

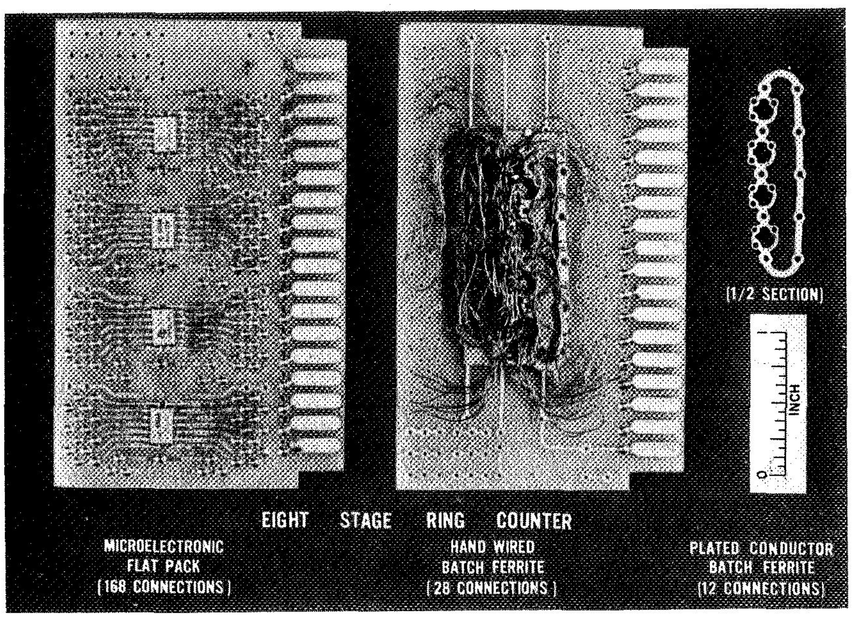


Figure 4–14. Reduction in connections in batch ferrite.

result, radiation doping was used to obtain a substantial improvement in the temperature-critical characteristics of semiconductor strain gages. More recently, radiation-doping techniques used in making infrared photodetectors from silicon produced detectors with better uniformity and stability than commercial photodetectors. The radiation-doping technique permits better process control in the manufacture of semiconductor detectors without increase in cost.

Scanning Imaging System.—Langley Research Center conducted preliminary tests of a laboratory version of a multispectral facsimile camera (an imaging and multispectral radiometry system) and completed a first analysis of its application in a planetary lander. The system is intended to demonstrate a simple but effective and reliable way of obtaining spatially well registered multispectral images; it is light (4 lb.), low in power requirements (6 W), small (2 in. dia., 6 in. long), and provides an adjustable scanning rate which can be matched to the data transmission rate.

Data Processing

Magnetic Logic Circuits.—A materials processing technique was

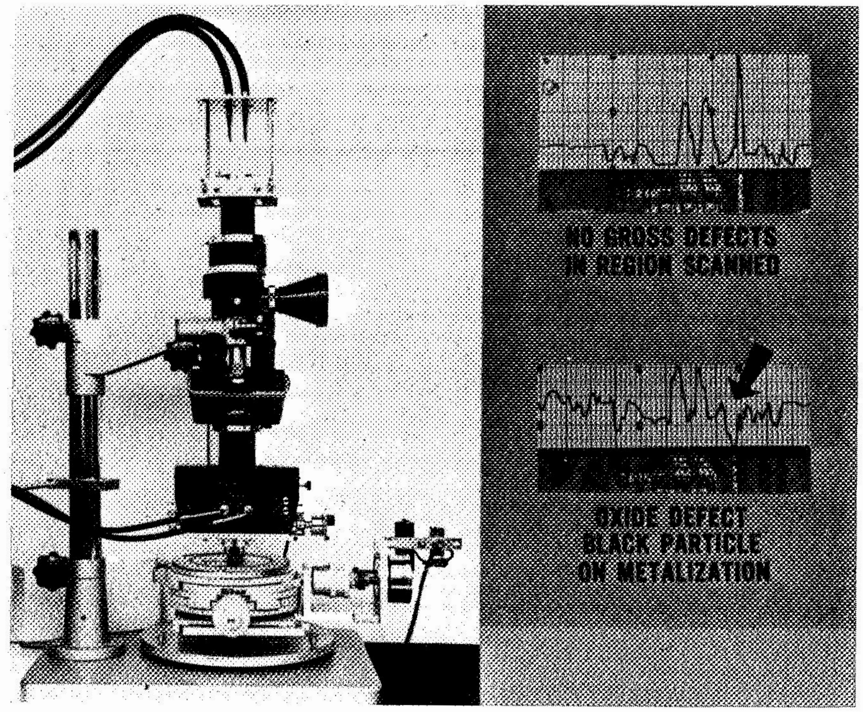


Figure 4–15. Automatic inspection.

developed that permits the batch fabrication of ferrite structures, thereby eliminating the individual ferrite cores required in previous all-magnetic logic devices. This is a major advance toward the development of small, low-cost all-magnetic logic circuits with high reliability and radiation resistance. Another important achievement was the construction and successful operation of several ring counters using batch fabricated devices. The counters are used for controlling the sequence of events in computers and telemetry systems. The advantage of batch fabrication of such devices is the reduction in the soldered interconnections which are a major source of failures in many electronic systems. (Fig. 4–14.)

Electronic Component Technology

Coplanar Triode.—A triode was developed which is coplanar (all elements are films on a flat substrate) and whose cathodes operate at relatively low temperatures (600° C. compared with 1,800° C. for conventional tubes). It will consume very much less power and

generate much less heat than conventional tubes. It is also very small so that a complete circuit (an operational amplifier) can be laid down on a single ceramic wafer about the size of a 5 cent piece and placed in a very small vacuum envelope. The coplanar technology makes active electronic devices available for use on inner planet or near solar missions. Work was also continuing to develop more efficient solid state devices for high temperature use.

Automatic Visual Inspection.—A method was developed to automatically examine each circuit of a high reliability microcircuit under a microscope to determine its quality and detect any defects. The system employs an ordinary light source which is scanned across the surface of a microcircuit. The reflected light is detected, converted to an electrical signal, and compared with a known standard to detect anomalies in the circuit. (Fig. 4–15.) The technique offers increased economy and reliability in microcircuit production, and should be the basis for complete automation of the inspection process.

AERONAUTICAL RESEARCH

Aircraft Aerodynamics

Current programs providing aerodynamic design information on wings, bodies, and combinations for speeds ranging from low subsonic to hypersonic were giving particular consideration to the fixed cropped double-delta wing planform. Such wings have found wide application in supersonic cruise transport and military aircraft, but very little systematic data are available for such wings as they are used on the SST, the A–11, and the Swedish supersonic fighters.

To furnish research information in this area, a systematic investigation was conducted, using modified subsonic compressible lifting surface theory with appropriate boundary conditions. Its purpose was to determine lift-curve slope, aerodynamic center, damping in roll and pitch, and lift due to pitch rate for nine families of cropped double-delta supersonic wings. (Fig. 4–16.) The results were compared with the limited available experimental data from wind tunnel tests, and found to predict reasonably well the principal aerodynamic characteristics of the wide variety of wings investigated. The same method was used to prepare a series of design charts for the double-delta planform wings in subsonic compressible flow.

Flight tests have indicated that the annoyance and potential destructive effects of sonic boom are likely to be aggravated by

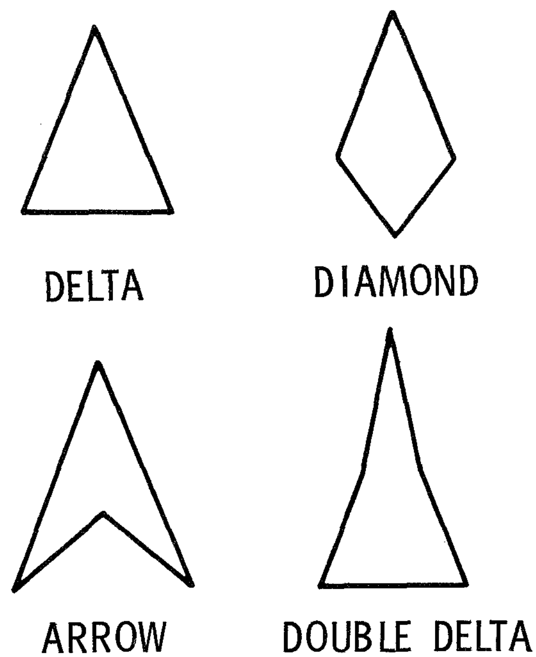


Figure 4–16. Wing planforms.

focusing of the shock wave flow field emanating from a supersonic airplane. Because focusing phenomena are difficult to study in nature, an arrangement was devised for studying sonic boom N-Wave focusing in the laboratory. Using a spark to generate and mirrors to focus the N-Wave, the system was able to produce both line and point focusing.

Experiments were conducted to evaluate two conflicting theories concerning the behavior of a sonic-boom pressure signature in the vicinity of a focus. It was found that a line focus was produced when an N-Wave was reflected from a two-dimensional parabolic mirror. (This finding agreed with the laws of geometric acoustics.) When the wave passed through the focus, it underwent a shift in phase of 90°. With a three-dimensional parabolic mirror, a point focus was produced, and the phase shift was 180°, resulting in a complete inversion of the wave. Thus, a classic theory predicting the failure of a focal point or line to form because of unknown nonlinear effects was shown to be basically in error and therefore the beneficial effects it suggested could not be relied upon to alleviate the problem in practice.

Aircraft Structures

The widespread use of cylindrical structures in aerospace vehicles requires accurate methods for predicting their strength. In a review of current methods, test data on stiffened cylinders which failed by general instability under uniform axial compression and/or bending were studied and buckling test data were compared with results obtained from a buckling theory. Buckling failures of well-constructed cylinders with about 45° waffle stiffening were experienced at loads as low as 65 percent of their calculated loads, and other cylinders of different construction (isotropic and corrugated cylinders with ring stiffening) failed at loads approaching the 65-percent value. Thus, it appears that testing has not revealed any type of stiffened cylinder construction that fails by general instability but is immune to low failing loads, and design methods which neglect the disparity between theory and test are likely to be unconservative.

In other work, titanium alloy skin-stringer panels were tested to evaluate the effect of various fabrication methods on the compressive strength. Fabrication methods included riveting, resistance- and arc-welding, tungsten inert-gas (TIG) and electron-beam fusion welding, and diffusion bonding. Panels machined from thick plate were also included. The maximum strength test results showed good conformity with results calculated by compressive strength analysis. Residual fabrication stresses were found to have a significant effect on buckling and a somewhat smaller effect on strength. Diffusion bonding and TIG fusion welding exhibited the least effect of fabrication.

Supersonic Aircraft

In research on materials that may have supersonic aircraft structural applications, pyrrones, a new class of heat resistant plastics, were given serious consideration. (*20th Semiannual Report*, p. 133.) Specimens of pyrrone foams were prepared and their thermal and mechanical properties evaluated. Chemically blown and syntactic foams were prepared in 1- and 2-inch diameter samples with densities ranging from 15 to 16 pounds per cubic foot. The compressive stengths and moduli of these unreinforced foams are high, and these properties are retained over a wide range of tempertaures from —100° F. to 700° F. Weight loss and dimensional shrinkage tests indicate that the foams remain stable for at least 100 hours at 550°F.

An experimental study was made of the influence of steady-state

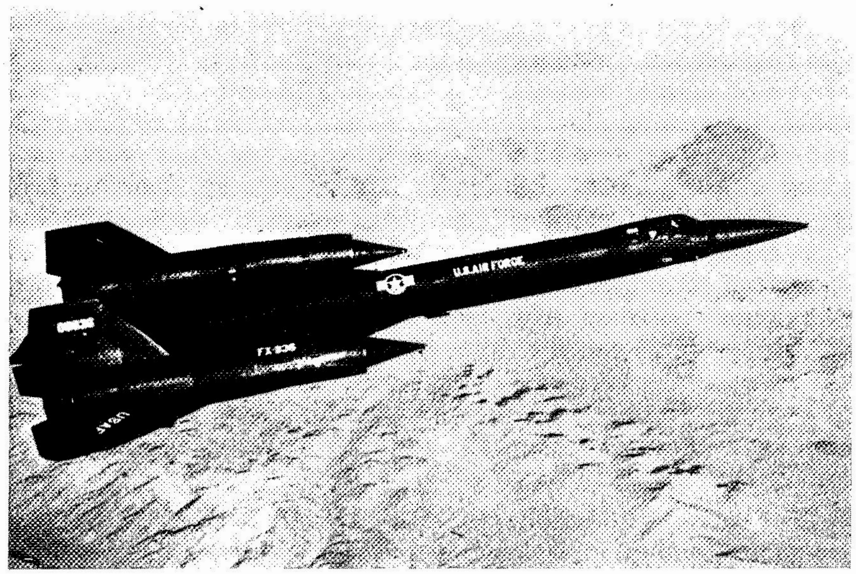


Figure 4–17. YF–12 airplane.

and dynamic pressure disturbances on engine system characteristics and operating limits. For this program, experimental techniques were devised for inducing the fan/compressor-inlet disturbances to replace the screens used in the past to induce steady-state pressure distortions. In the new technique, secondary air is injected through an array of small nozzles uniformly distributed in a plane normal to the inlet duct centerline to achieve air momentum interchange with the primary air forward of the fan/compressor face. By controlling the secondary-air distribution and flow rate, variable amplitude steady-state or dynamic pressure distortions or dynamic uniform pressure oscillations can be produced. Good agreement was achieved between the results obtained in tests with pressure distortions made by a screen and by the air-jet distortion simulator. When the results between flight and ground tests are correlated, it should be possible to reduce the amount of expensive flight testing currently required in an aircraft/engine development program.

With the conclusion of the XB–70 and X–15 programs, a joint NASA–USAF supersonic research plan was formulated to continue aeronautical research and development using YF–12 aircraft capable of sustained mach 3 flight. (Fig. 4–17.)

In this two-phase flight research program, phase I is oriented primarily toward Air Force interests which include a further definition of the tactical performance and support requirements of an advanced interceptor, and phase II is oriented primarily toward NASA objectives, which include investigations of propulsion system, airframe-propulsion system interactions, stability and control predictions of an aerothermoelastic airplane, structural deformation and flight loads, and aerodynamic characteristics.

A NASA–USAF Memorandum of Understanding which covers such areas as test management, operations and specific loan arrangements of the aircraft was executed on June 5, and the first YF–12 flight took place on December 11. The airplane was in flight over 2 hours, flew faster than Mach 3, and reached an altitude exceeding 70,000 feet.

Hypersonic Vehicles

An investigation was conducted at Mach 6 to determine the interference effects of jet exhaust flows on a typical hypersonic cruise configuration and to evaluate a theory for predicting the effects. The overall results show that proper utilization of the underexpanded jet exhausts from ramjet engines can extend the cruising range of a Mach 6 hypersonic transport by 5 percent; the increase results from direct improvements in lift-to-drag ratio and from reduction in the aircarft trim drag penalty. The theory predicted adequately these performance improvements.

A preliminary study was made of the feasibility of using an active cooling system for the wing, fuselage, and tail surfaces of a Mach 6 transport vehicle. A candidate system was identified: a liquid convective system in which water-glycol or a silicon-based coolant circulates through the wing skin combined with a hydrogen cooled heat exchanger. The results indicated that at the cruise condition an uninsulated aircraft can be maintained at 400° F. Thus, it may be possible to use a light-weight, long-life structural material such as titanium rather than the heavier superalloys which are required for an uncooled aircraft.

The hypersonic Research Engine project progressed through the definition and design of all components. (Fig. 4–18.) The aerothermodynamic integration model with internal passages designed for high propulsive efficiency and the structural assembly model with regeneratively cooled surfaces were being assembled. Facilities were being modified to demonstrate the overall operating perform-

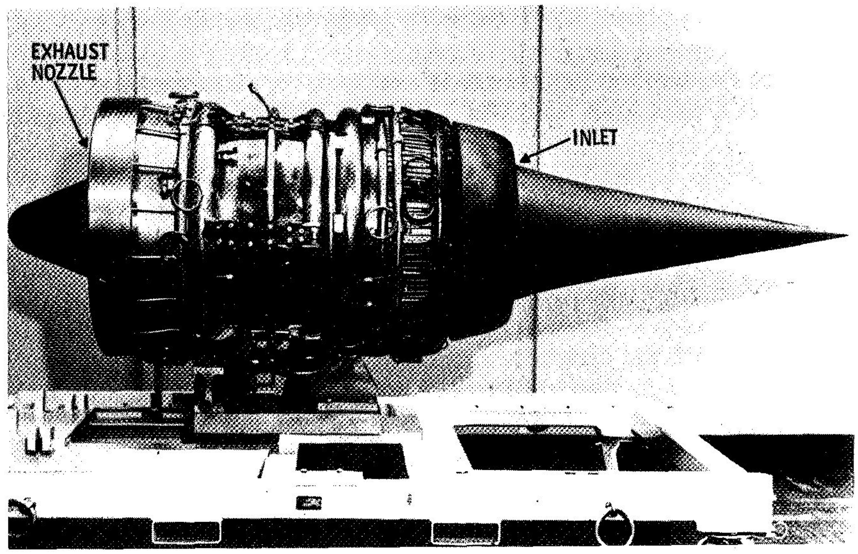


Figure 4–18. Hypersonic research engine mockup.

ance of the engine with either subsonic or supersonic hydrogen combustion at simulated flight speeds up to Mach 7, and to determine the structural adequacy of liquid hydrogen regeneratively cooled surfaces operating in a hypersonic environment.

V/STOL Aircraft

Rotorcraft.—Theoretical and experimental studies of ways to increase the high-speed performance and maneuvering ability of rotary-wing aircraft have indicated that the lifting and propulsive capability of the rotor decreases as speed increases. Thus, to maintain the hovering and low-speed capabilities of a rotor and at the same time improve its high-speed performance, additional sources of lift and/or propulsive force are required.

For testing purposes, several helicopters have been modified to incorporate various methods of compounding (adding auxiliary propulsion and/or wings). A hingless-rotor compound helicopter completed a flight-test program in which data were obtained on level-flight performance characteristics, speed stability, maneuver stability, and wing-rotor lift sharing in maneuvering flight. Rotor rotational-speed control characteristics during maneuvers and during simulated main-rotor power failures were also studied.

The results showed an inherent reduction in rotor lift as level-

flight airspeed increased. In addition, a reduction in rotor-lift sensitivity in maneuvering flight was measured and determined to be dependent on the stability of the aircraft in maneuvering flight. Although the lift-sharing trends contribute favorably to the piloting task in the compound mode, the rotor overspeed tendencies could require constant pilot attention during maneuvering flight.

Jet VTOL Aircraft.—One of the problems associated with jet VTOL aircraft is hot-gas ingestion. The problem is serious because a thrust loss occurs as a result of the elevated temperature of the engine-inlet air or an uneven inlet temperature distribution across the engine face. Much of the research into the problem of hot-gas ingestion has relied heavily on experimental work, which is continuing to provide information for improving understanding of the effects of the factors involved.

A recent study of hot-gas ingestion, conducted in the Langley full-scale tunnel on large-scale jet VTOL fighter-type aircraft configurations, investigated several nozzle and inlet arrangements, wing sizes, and wing locations for a range of forward and sidewind conditions. The exhaust-gas source was a turbojet engine which normally operates at a nozzle pressure ratio of about 1 to 8 and a nozzle temperature of 1,200° F., but did not achieve this pressure ratio in many of the tests because of the hot-gas ingestion.

The ingestion of hot engine-exhaust gases into the inlets was found to be very dependent upon the aircraft configuration and upon the windspeed. The only arrangement of engine-exhaust nozzles that did not result in relatively high hot-gas ingestion was an in-line arrangement, which resulted in virtually no hot-gas ingestion. A rectangular arangement of nozzles resulted in an inlet-air temperature rise above ambient of 100° F. to 200° F. for many test conditions.

The ingestion of hot exhaust gases was greatest at windpseeds from zero to about 20 knots; virtually no ingestion occurred at windspeeds greater than about 30 knots except for the configuration with a single-nozzle arrangement which still had a considerable amount of ingestion at the highest test speed of about 37 knots. Top inlets were, in general, less subject to hot-gas ingestion than side inlets, and a low-wing position and increased wing size were found to reduce the ingestion of some configurations. Deflecting the exhaust gases 25° rearward with vectoring nozzles generally eliminated the ingestion of hot exhaust gases.

Simulation of V/STOL Flight Characteristics

The Ames 6-degrees-of-freedom motion simulator was designed to overcome limitations in motion simulation and shortcomings in the visual presentation capabilities of all ground based simulators. The Ames device can traverse an 18-foot cube of space, making it possible to perform small hovering maneuvers without motion washouts (filters superimposed on the drive signals to attenuate the command displacement) and an artificial visual system.

To determine the ability of the simulator to perform research in the hovering flight regime, it was compared with the jet-lift X–14A aircraft during concurrent operation on an identical research problem. Characteristics of the aircraft were simulated, and results for the roll and pitch axes were compared with flight data. Control power and damping requirements for the roll and pitch axes compared very well with flight data. The simulator's motion quality was considered outstanding for VTOL hovering flight. Its travel limits were large enough to simulate hover-maneuver tasks on a one-to-one scale—without the need for an attenuation of the drive signals.

Wind Tunnel Wall Interference Data.—Despite extensive work on the interference flow caused by wind-tunnel boundaries, actual wind-tunnel practice is not always precise with regard to obtaining the correct wall interference factors for a given test. Unless the proper factors are readily available the tendency is to use an available "small model" factor rather than the appropriate finite-span factor; this practice is particularly common in the testing of V/STOL models, where the configurations range over such a wide variety of types that the required factors are seldom available. It is common in V/STOL tests, other than those intended specifically to study wall effects, to ignore wall interference, largely because of the inconvenience of obtaining the correct interference factors.

Modern digital computer equipment, together with simple superposition techniques, can greatly simplify the problems involved in obtaining the proper interference factors for models of arbitrary configuration. In recent work, programs were developed for calculating the interference factors for a wide variety of V/STOL and conventional aircraft configurations.

Sample numerical results from analyses of several specific configurations indicated that a large number of variables, such as wind-tunnel configuration, wake deflection, model location, span of wing and tail, load distribution, sweep, angle of attack, pivot location, tail length, and tail height, may individually or collectively

produce substantial effects on wall interference. It was also found that interference is particularly severe at the rear rotor of tandem systems, and the maximum size of such systems for reasonable wall effects was determined.

BIOTECHNOLOGY AND HUMAN RESEARCH

Human Research

Several topics were being investigated in this part of the NASA effort to increase knowledge of man in space. One project was concerned with microbiology in spacecraft where the transmission of microflora between crewmen may increase due to the closed environment, the distribution of microbe-laden particles may be changed because of the lack of gravity, host resistance may change, microbial mutations may occur with more virulent forms resulting, and latent infections may be activated. A technique for combating such microbiological problems was shown to be clinically feasible: it replaces a virulent strain of microorganism with a similar but nonvirulent one. In three patients tested, abscess formation due to a pathogenic strain of staphylococcus was abated when a nonvirulent staphylococcus strain was implanted. This finding may also have important implications for the clinical treatment of infectious diseases.

Another project tested the theory that the absence of weight bearing by the lower legs may be responsible, at least in part, for skeletal decalcification in a weightless environment. In this work, a skeletal stressing apparatus was used to apply loads approximating body weight to the lower limbs of restrained monkeys. The loads were applied cyclically, and calcium loss in these animals was found to be less than in those restrained but not skeletally stressed. Additional studies were underway to test the findings on human subjects.

Finally, in bioinstrumentation research, optical techniques were applied to the measurement of blood gas constituents. The technique takes advantage of the fact that the internal blood vessels of the eye normally contain blood which is oxygenated to the arterial blood level, and the eye may therefore be used as a "window" to see the oxygenated blood. The instrument used in this work irradiates the back inside surface of the eye with red and infrared radiation and detects and measures the reflected energy. The ratios of the reflected red and infrared energy are utilized in the instrument to automatically calculate the blood oxygen level in the measurement area. (Fig. 4–19.)

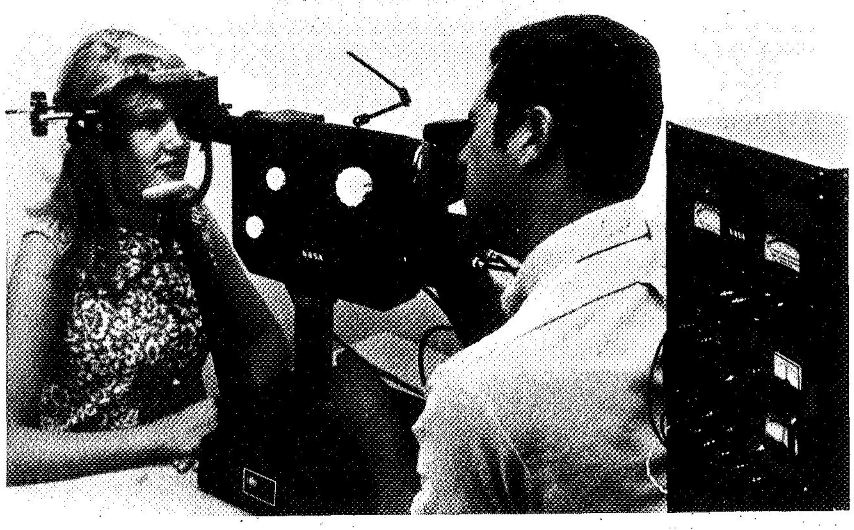


Figure 4–19. Measuring blood oxygen level in the eye.

Man-Systems Integration

In a continuing program to study the habitability of space vehicles, the Manned Spacecraft Center investigated mobility of astronauts inside a space station, eating arrangements, constant wear intravehicular garments that are comfortable as well as functional, and the architectural arrangement of the interior space.

In another study, criteria were developed for use in determining when remotely controlled manipulators are more efficient than astronauts for extravehicular activity and when the astronaut can perform more efficiently. Marshall Space Flight Center will publish the criteria for use in system design and mission planning.

And, the Lunar Landing Research Facility and the standup cab developed and used by the Langley Research Center to study lunar flying vehicle dynamics were used by the Apollo 11, 12, and 13 crews for training. (Fig. 4–20.)

Life Support and Protective Systems

Life support systems for space missions of 30 days and longer will utilize regenerative processes to reclaim essential materials from human waste products. On missions which will not have resupply capability, the life support systems must operate at maximum efficiency to insure optimum use of the onboard materials. An

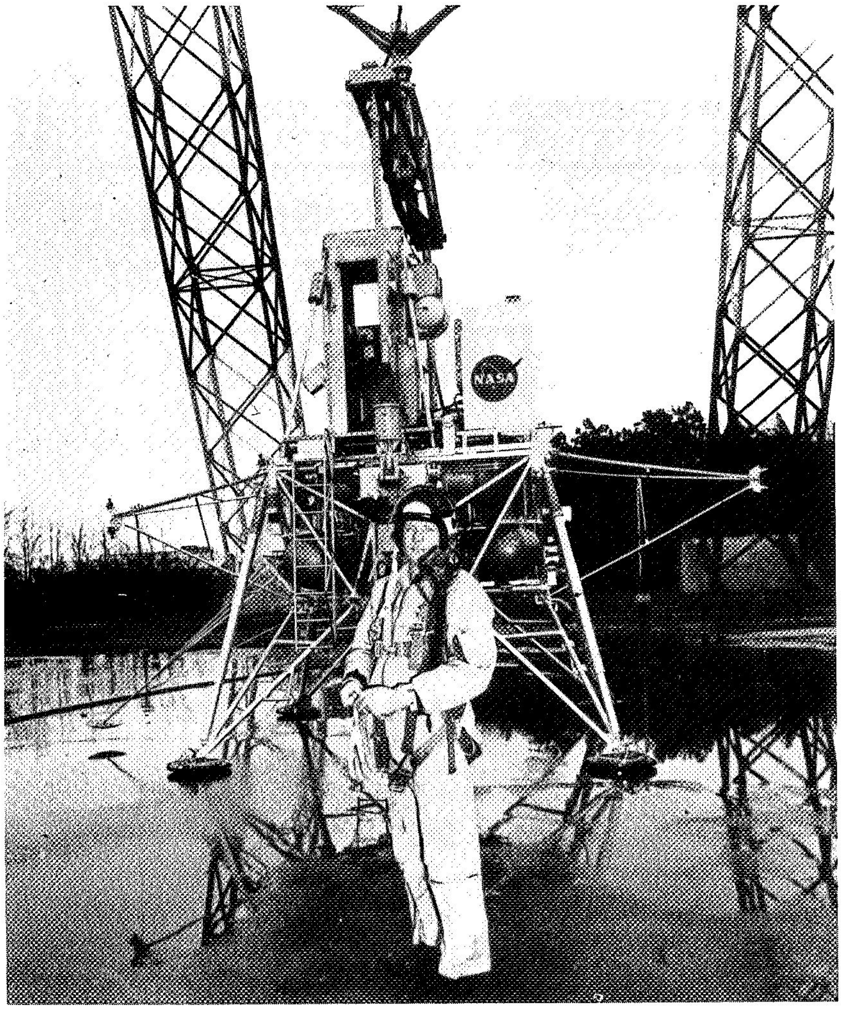


Figure 4–20. Astronaut Armstrong in front of standup cab.

efficient life support system must be able to independently control liquids and gases flowing in zero gravity to and from various subsystems where they are processed at differing pressures, temperatures, and flow rates. Undesired mixing of the liquids and gases contaminates the liquid transport lines with trapped gas bubbles. The bubbles, carried downstream by pumps, cause inefficiencies and measurement errors, and may produce system failure due to gas blockage.

To overcome this potential source of trouble, the Langley Re-

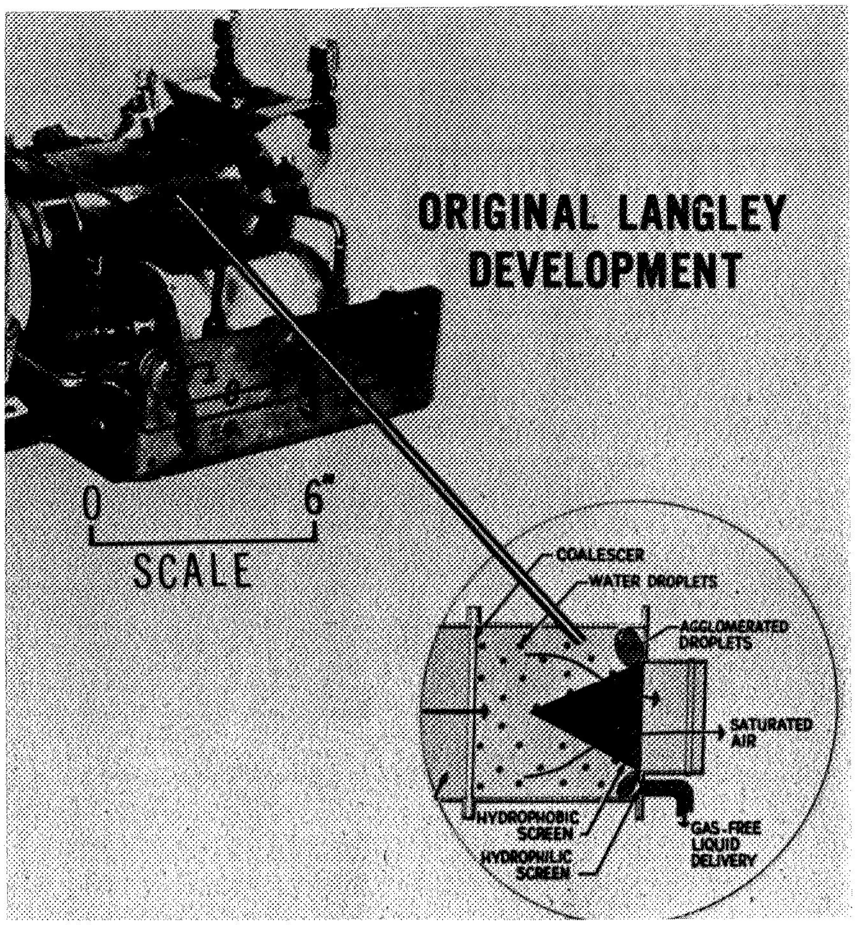


Figure 4–21. Static two-phase separator.

search Center began to develop a static two-phase separator capable of operating in zero gravity. Static separation of liquids and gases in a liquid transport line was achieved by using materials with different hydrophilic and hydrophobic characteristics. Fibrous porous Teflon and glass fiber cloth sprayed with Teflon proved to have the best hydrophobic qualities while stainless steel wire woven screen and nickel wire woven screen were the best hydrophilic materials.

Of several design configurations tried, the most successful in removing air from water in a spacecraft cabin is shown in Figure 4–21. The device employs the same principle as a water gun used in

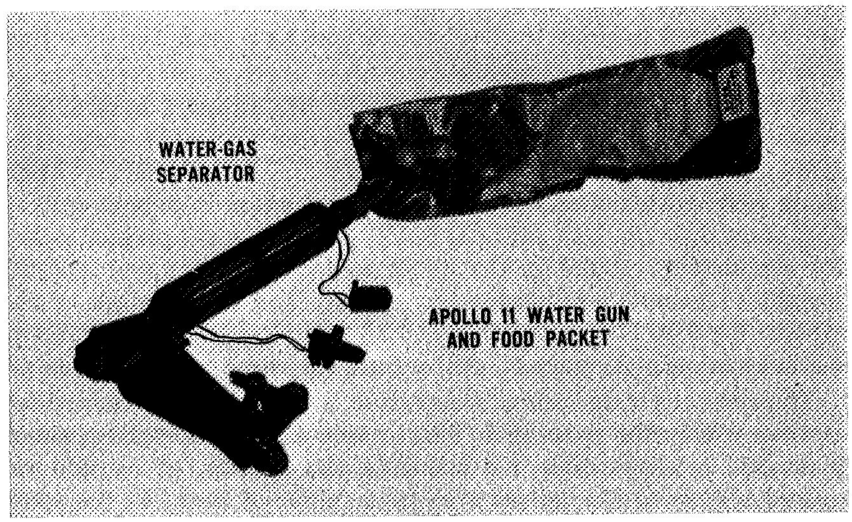


Figure 4–22. Apollo 11 water gun.

the Apollo 11 and 12 spacecraft for hydrating the food (fig. 4–22). On those flights, the water was produced in the fuel cells at approximately 200 pounds per square inch absolute (psia) and was saturated at this pressure with hydrogen. Then the water was stored in a bladdered tank at 25 psia, and finally used at the cabin pressure of 5 psia. The total pressure reduction released approximately 8 percent by volume of hydrogen gas from solution at the point of use. On earlier missions without the gun this hydrogen caused problems for the astronauts. Use of the gun provided the astronauts with almost gas-free water for rehydrating food.

In another part of the life support program, a detailed analysis was completed on future life support system concepts and their integration with other systems in space vehicles for missions lasting up to 500 days. All subsystems were considered to be closed loop except for the food (food regeneration is not considered feasible before 1980 at least). All aspects of life support were reviewed, including atmosphere control and the recovery of oxygen from metabolically produced carbon dioxide, the regeneration and reuse of metabolically produced water, crew hygiene problems, food management, thermal and waste control, reliability and maintainability, and the unique problem of compartment replacement in zero gravity. It was concluded that future space vehicles should be equipped with a shower which would operate in zero gravity with the assistance of properly directed airflow, and that clothing

should be washed to reduce resupply requirements. The results are being used in space station studies and as a basis for directing research and technology efforts.

A prototype, lightweight contingency life support system was developed for the Manned Spacecraft Center by a contractor. The system includes three technologically advanced features: a "breathing vest" which allows for a fourfold reduction in helmet oxygen flow rates over the conventional flush system; a gas-operated pump for circulating coolant in the liquid cooled garment; and a lightweight (1 pound) sublimator for cooling. The total weight of the system for 0.38 hour operation is 30.6 pounds and for a projected 3.5 hour mission 39 pounds, still within the same volume envelope.

The system's most radical innovation is the breathing vest which is worn within the space suit. This unique element, weighing about 8 ounces, is responsible for reducing the amount of oxygen required to flow to the helmet area by a factor of four. At the same time, it maintains the level of inspired carbon dioxide within acceptable limits. Because of the fourfold reduction in oxygen flow requirements to the helmet, an open-loop design could be chosen. With an open-loop system design there is no requirement for a gas recirculation fan with its associated battery, for a condensate water removal system, or for a carbon dioxide absorbing system. Without these three subsystems, the portable life support system's weight, volume, and complexity are significantly reduced.

Biotechnology Flight Projects

Preparations were continued for key experiments to expand understanding of man in the weightless environment. In one such experiment, primates will be exposed to zero gravity for 6 months to 1 year; as the experiment progresses, physiological changes that take place down to the cellular level will be analyzed and evaluated.

During the period, fabrication was completed of a feasibility demonstration model of each of two competing designs for the life support and performance testing hardware that would operate in zero gravity without failure for the required long periods. Primates were tested with the equipment; the longest duration was a 56-day continuous run. Minor equipment failures occurred but the basic design appeared sound. The animals thrived in their life cells, put on weight, and increased their performance efficiency. (Fig. 4–23.)

In parallel with the tests, scientists at the NIH Yerkes Regional Primate Facility in Atlanta and at the University of Illinois were

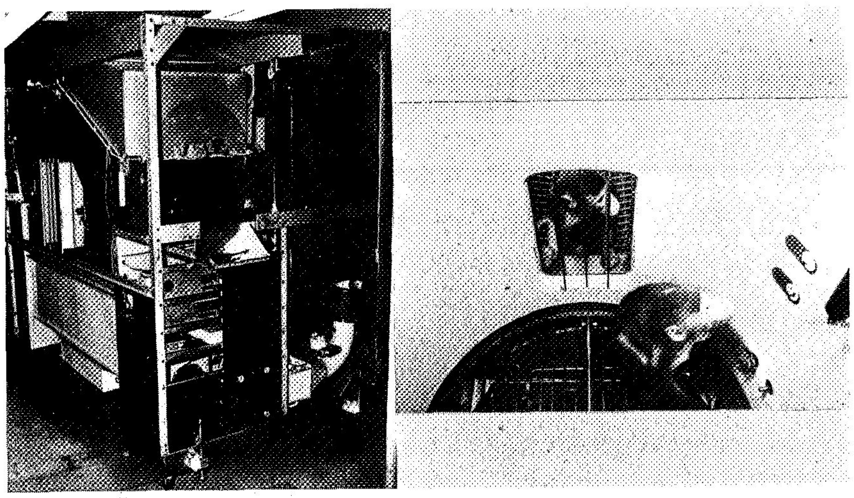


Figure 4–23. Life support test equipment.

establishing the basic 1-G background medical data against which the flight data will be compared. Yerkes also set up a minimum primate breeding compound to assure the availability of healthy animals for the experiment.

ADVANCED PROPULSION SYSTEMS

The Chemical Propulsion Research and Technology Program supports goals arising from probable future NASA propulsion requirements. Its objectives include the advancement of capabilities in engineering disciplines, the design and testing of key components, improvements in space propulsion system performance, advances in component reliability, and better understanding of the factors affecting selection of any propulsion system to meet the requirements of a specific mission.

Solid Propulsion Systems

The first experimental high energy hybrid system proposed for upper stage applications and planetary missions was fired successfully, producing an equivalent specific impulse of 385 seconds. A hybrid system is one in which the propellants are part liquid and part solid. The motors, which weighed about 3,000 pounds, developed over 10,000 pounds of thrust.

The liquid propellant was a mixture of fluorine and oxygen, the

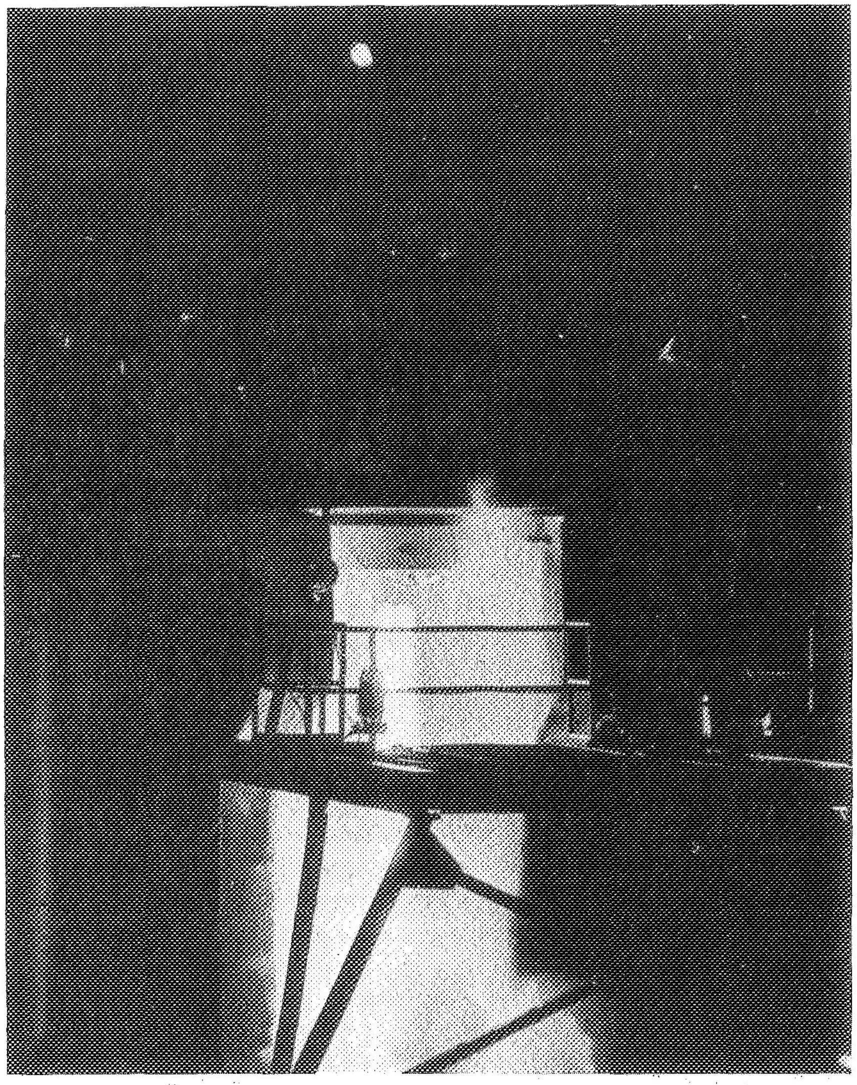


Figure 4–24. Hybrid system test.

solid a mixture of lithium, lithium hydride, and rubber. The first motor was fired once for about 15 seconds, stopped for inspection, then refired for about 50 seconds more. Performance was satisfactory. The second motor was fired for a single pulse lasting about 35 seconds, with similar results. (Fig. 4–24.) Small scale motors containing a 400-second impulse fuel combination were also success-

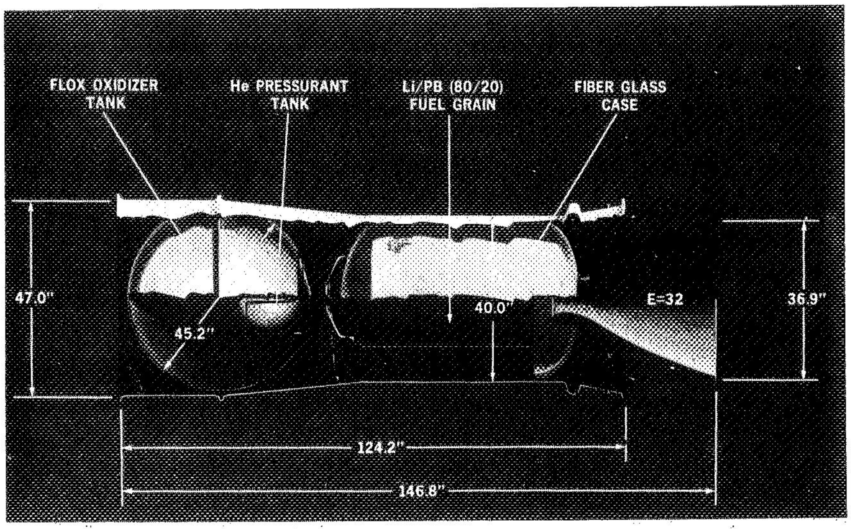


Figure 4–25. Hybrid motor.

fully test fired and will be tested on a 3,000-pound version in 1970. (Fig. 4–25.) The liquid component in this system is also fluorine and oxygen, but the solid is much higher in lithium content.

Another spacecraft propulsion system which made satisfactory progress in its test program, is a solid motor with a very low thrust and a long burning time. It would be used with spacecraft payloads which have extended booms and are therefore sensitive to acceleration. Current test motors use existing hardware and the new low-burn-rate propellant. A motor weighing 800 pounds and several 60-pound motors have been fired. By casting the motors essentially full of propellant, without a central bore, and burning only on the end, it was possible to attain burning durations two to three times as long as those originally produced in this hardware. This motor concept has the potential for exceptional propellant-weight efficiency—up to 93 percent. It is a candidate for use on a Jupiter orbiter mission and other missions requiring a reliable orbit insertion motor after lengthy exposure to space conditions during planetary transfer. (Fig. 4–26.)

Under a third spacecraft propulsion program, the manufacture of a 3,000-pound high energy restartable solid motor was completed. Plans were made for test firing this motor in early 1970. It is expected to develop the highest specific impulse of any solid propellant space motor—about 325 seconds. In the first test, a system for stopping the motor on command will be demonstrated. In

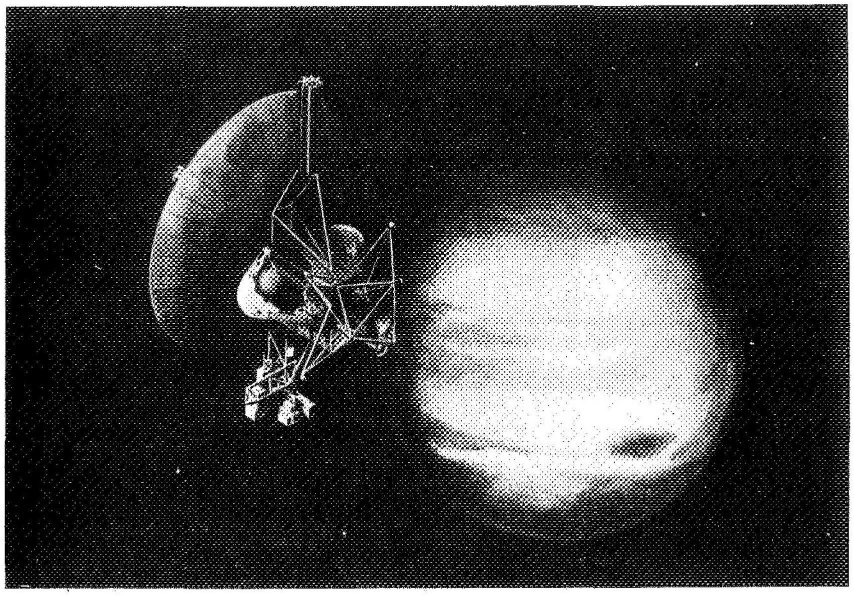


Figure 4–26. Low thrust solid motor.

addition, preparations were underway for follow-on tests to show stop, restart, and a final stop, ultimately under simulated altitude conditions. (Fig. 4–27.)

The technology program for large solid motor components continued as contracts were let to study low-cost materials of motor cases, nozzles, insulation, and propellants. Other areas being studied included propellants with improved processing characteristics, methods of inspecting large motors, and ways of handling and transporting motors. Work on materials, components, and subsystems resulted in improvements in nozzles for hotter propellants and restartable systems.

Propellant research emphasized binder development, processing and handling of more energetic systems, and fit of propellants to specific missions. Significant progress was made in development of lower burning rate propellants that do not suffer a performance loss (and are thus suitable for planetary spacecraft applications). Progress was also made in a number of other areas: a new propellant binder (principally a saturated aliphatic hydrocarbon) was developed; it is potentially compatible with reactive oxidizers and is stable with ammonium perchlorate under heat-sterilization conditions and in the space environment. A theory of viscoelastic behavior was evolved and substantiated; it makes it possible to

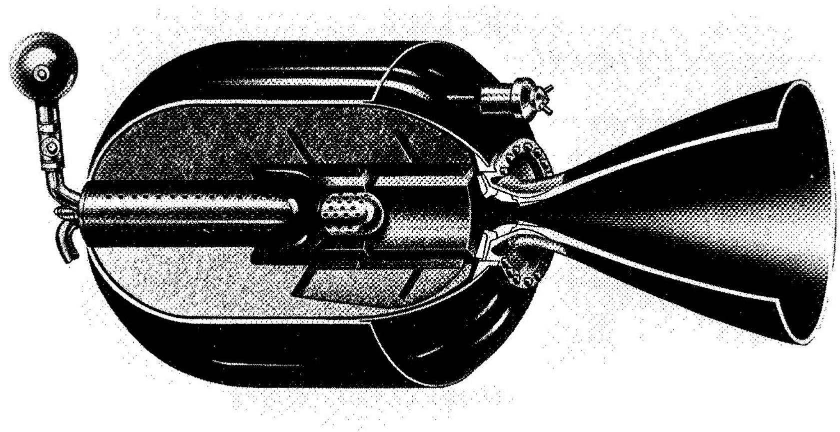


Figure 4–27. Restartable space motor.

predict more accurately the response of solid propellants to generalized stress-time-temperature fields. This ability is important because of the catastrophic nature of solid propellant grain failure. The scanning electron microscope was used to study solid propellant combustion. Its use gave researchers new knowledge and experimental methods which offer a basis for more realistic qualitative modeling of propellant combustion and potential means to control combustion characteristics. Improved analytical techniques were established for determining rocket plume characteristics in space and in planetary atmospheres. This work is important because there are indications that rocket plumes have caused interference with scientific instruments or have exerted unexpected forces on spacecraft.

Also, techniques for ignition of pyrotechnics by laser were investigated. Such methods of ignition offer advantages—immunity from radio frequency interference, elimination of bridgewires, and the potential ability to ignite less sensitive mixtures thereby enhancing safety.

Lastly, significant progress was made in establishing accept-reject criteria for defects in fiber glass rocket motors with the development of ways of repairing defects that would otherwise cause rejection of the motor, and the refining of analytical techniques for consideration of damaged motor cases.

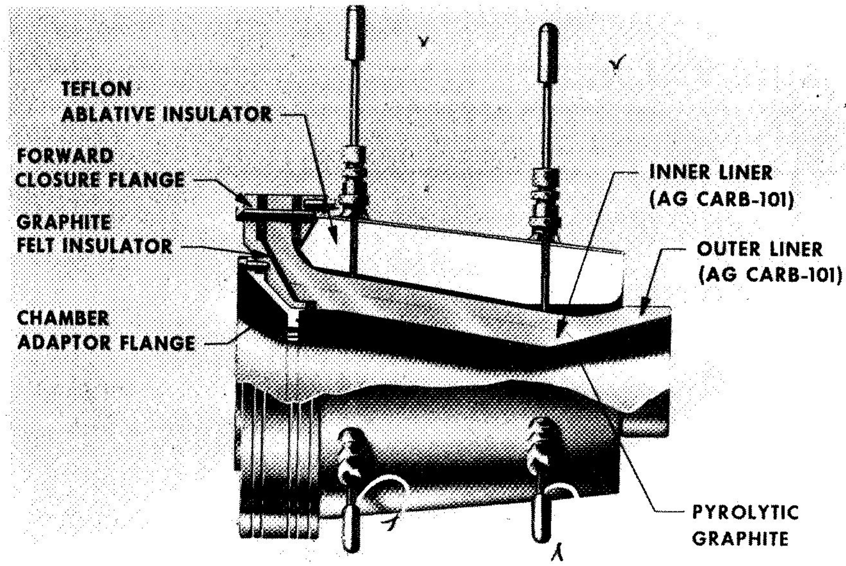


Figure 4–28. Oxygen difluoride-diborane chamber assembly.

Liquid Propulsion Systems

The problem of reliability is being given considerable attention in designing and testing space station components which will be capable of operating for a year or more on manned missions and for about 10 years in the case of unmanned spacecraft propulsion units. To avoid future propulsion system operational problems, space ignition, venting, and similar problems associated with high energy propellants and new propulsion system designs were being thoroughly investigated.

The new component technology program included intensive effort to devise a thrust chamber for very long duration firings with OF_2-diborane propellants. Carbon chamber liners effective with other fluorine-oxidized systems were chemically attacked by the boron compounds. It now appears possible to regeneratively cool a metal-walled chamber using vaporized diborane, and if this is possible, the usefulness of this high energy space storable system may be extended to entirely new applications.

Research on combustion stability and heat transfer continued to make steady progress. Design capabilities for acoustic liners to control stability were improved, and a better understanding of the parameters affecting transpiration cooling was obtained.

Work on the very high energy tripropellant system, Lithium-

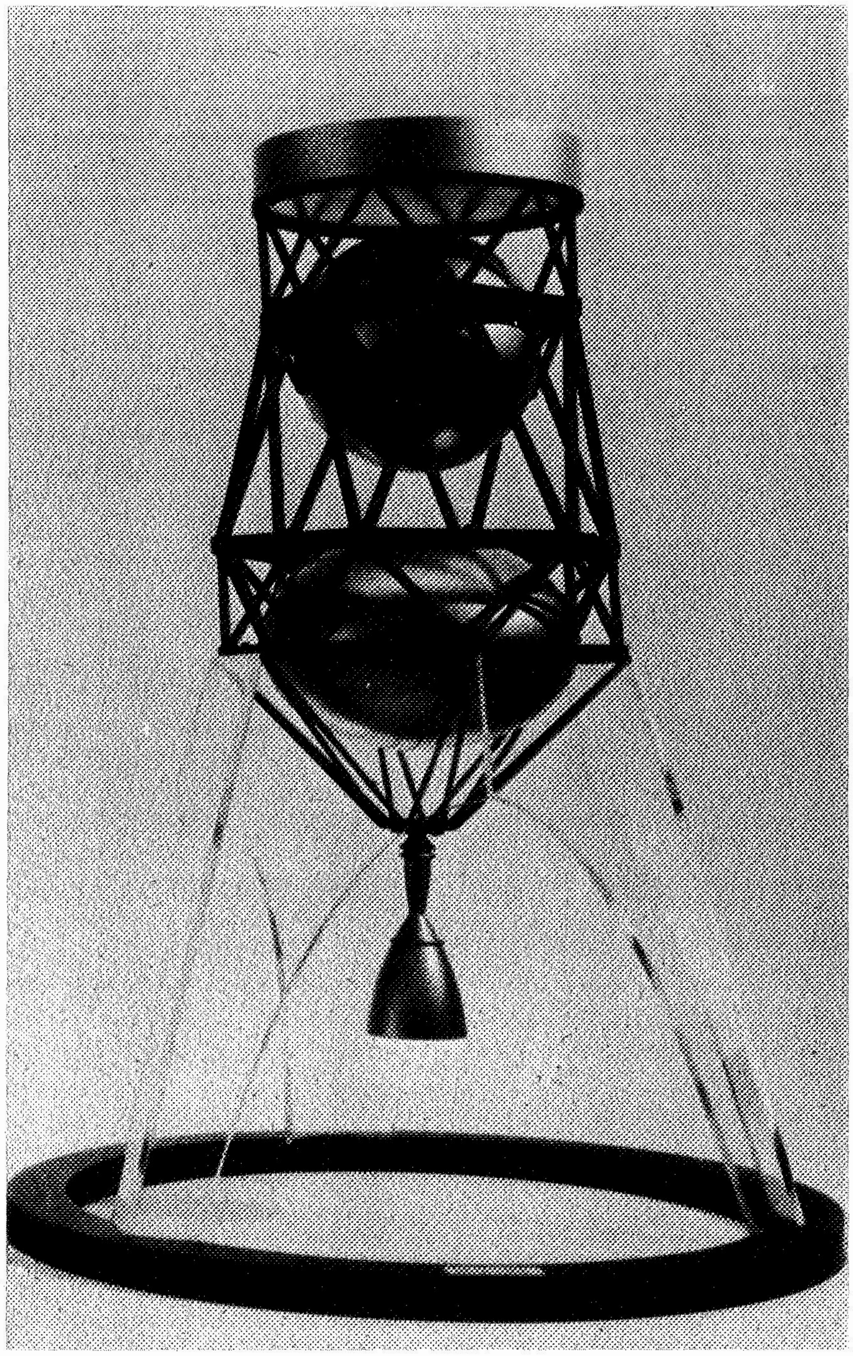


Figure 4–29. FLOX-methane propulsion module model.

Fluorine-Hydrogen, was reduced following a very successful feasibility test. A specific thrust of 508 seconds was recorded in an altitude facility—the highest chemical rocket performance yet achieved. However, vehicle analyses show only modest payload improvements over an equally advanced fluorine-hydrogen system, the weight of the three propellant feed systems nearly canceling out the performance increase over a bipropellent system. Work on this project will resume when funding is available and suitable missions are identified.

In the experimental liquid engine systems area, a new approach was made to fabricating the segments of an aerospike thrust chamber. The new method, which involved castings in a copper alloy with an electrodeposited nickel closure of coolant passages, apparently will make it possible to achieve significant cost reductions. The liquid hydrogen and liquid oxygen high pressure engine concept became ready to enter the development stage. It will be the foundation for the main propulsion for the Space Shuttle. At the JPL Edwards Test Site, a test stand was converted to operation with the space-storable propellant combination oxygen difluoride/diborane, and testing of experimental thrust chambers was begun (fig. 4–28). At the Lewis Research Center, another space storable propellant combination, a mixture of fluorine and oxygen (FLOX) with liquid methane, was being studied; it demonstrated high combustion efficiency and good cooling capability. In addition, detailed analyses of engine cycles and component layouts suggested an optimum engine configuration (fig. 4–29).

BASIC RESEARCH

Fluid Physics

A significant advance in gas dynamic laser research was achieved with the demonstration of an all-chemical laser. Developed under NASA sponsorship, the new laser is the first to be activated for continuous operation by mixing commercially available bottled gases. (Fig. 4–30.) This chemical CO_2 laser, which requires no external energy sources to excite the reactants, is compact, simple, and efficient. Such lasers are potentially useful for applications in space communications and power transmission to satellites.

The research program on sonic boom prediction and reduction also made good progress. The program provided techniques for predicting the pressure waves from aircraft maneuvering through a nonuniform atmosphere and extended current theories to include

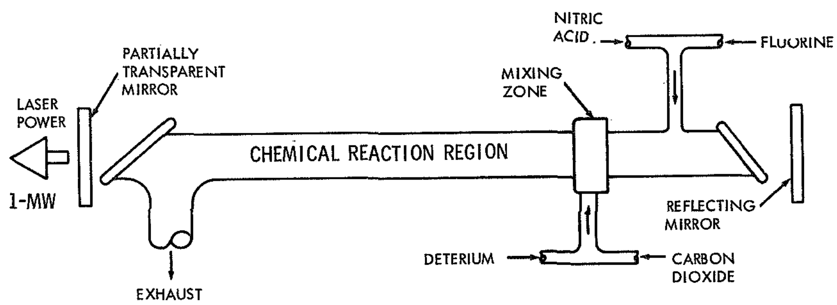


Figure 4–30. Schematic diagram of all chemical laser.

the effects of unsteady winds and atmospheric turbulence. In addition, several theoretical investigations of aircraft configurations indicated that significant boom reductions are potentially feasible; the theoretical concepts to achieve the reductions were being evaluated in the NASA wind tunnels.

Wind tunnel studies were made of the interaction and dispersion of atmospheric pollutants from airborne and ground sources in urban areas. Models of typical buildings and street layouts were tested in a low-speed wind tunnel. The tests indicated that perpendicular to the wind direction, there appears to be low ventilation, or a high concentration of pollutants into the adjacent streets. Figure 4–31 shows this result from a single source of pollution (left) and from multiple sources. The wind, blowing at right angles to the street, creates vortices at the vertical edges of the buildings. The smoke is thus confined in the street, producing a highly polluted area.

Applied Mathematics

The applied mathematics program is stressing research in information sciences and problems of information utilization. The new information sciences effort is designed to build bases for:

- Automatically recognizing visual patterns (cloud formations, air and water pollution characteristics, crop damage, etc.);
- Improving the performance of men and machines through interactive problem solving;
- Storing and retrieving information effectively and efficiently;
- Designing self-adaptive machines (or robots) that can perform tasks without the need for direct human intervention;

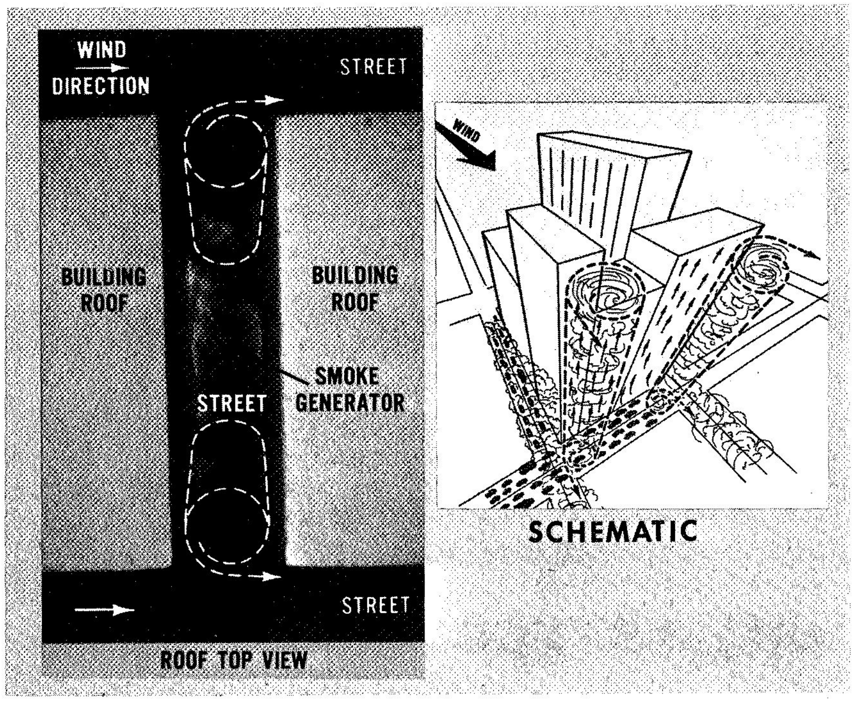


Figure 4–31. Dispersion of pollutants in city streets.

- Utilizing new mathematical research and discoveries in such areas as linguistics, graph theory, automata theory, logic, and mathematical programing.

- Verifying the correctness of computer programs, leading toward automatic programing.

Although the research is intended primarily to support NASA space and aeronautical objectives, its results should contribute to other technological approaches in pollution, health, transportation, and education.

In pattern recognition research, where recognizing speech automatically has been one of the prime objectives, worthwhile progress was made with the building of a system capable of evaluating competing speech recognition methods quantitatively. (Primary speech recognition methods are statistical analysis of the acoustic wave; linguistic analysis of the distinctive features; and "analysis-by-synthesis" or modeling the vocal tract and correlating the received signal with a signal that could be produced by a vocal

tract.) The NASA speech program evaluation system can point out possible theoretical inadequacies of a particular method as well as give generalized guidance for future research.

Materials

In research on silicon impurities, investigators at the NASA Langley Research Center achieved, for the first time, a controlled introduction of magnesium and beryllium impurities into high purity silicon. This is an important step forward because the electronic properties of silicon, probably the single most important electronic material, depend strongly on the kind and amount of impurities which can be introduced into the silicon lattice. Work was continuing in an effort to understand how magnesium and beryllium impurities modify the silicon electronic structure. The ultimate aim of this work is to extend the range of usefulness for this most important electronic material.

Epitaxial growth—the growth of ordered thin films on crystalline substrates—is widely used in fabricating transistors and microelectronic devices. However, the process is sensitive to the presence of surface impurities, and little is known about the basic mechanisms by which surface contaminants inhibit good film formation. NASA researchers at the Electronics Research Center studied the effects of oxygen, a contaminant, on the epitaxial growth of germanium, a semiconductor used in electronic devices. They found that the presence of surface oxygen inhibits epitaxial growth by providing nucleation centers for the formation of germanium oxide. They also found that in the presence of oxygen there is a significant rise in the temperature at which epitaxial growth occurs.

The high-temperature-resistant pyrrone polymers, developed by the Langley Research Center, were fabricated, for the first time, as foams with densities of 30 to 60 pounds per cubic foot. The two methods for foaming these high modulus, rigid polymers—the use of a blowing agent or the addition of a lightweight filler, such as glass microballoons—are adaptable to the fabrication of large foam sections. Because of their heat stability up to 550° F, the foams were being evaluated for use in composite structures on high speed aircraft such as the SST, as well as for such applications as thermal insulation, ablative material, and high temperature dielectric insulation. (P. 99 also.)

Glass fiber composites are the preferred materials for much composite construction because they are light, strong, and rela-

tively cheap. However, they have the great disadvantage of a low modulus of elasticity, or a lack of stiffness, which makes them unsuitable for large thin-walled structures subject to buckling. This disadvantage seems to have been reduced, for recent research by a NASA contractor showed that glass fibers with twice the stiffness of present day commercial fibers are possible. The improved fibers, used as reinforcement for epoxy plastics, are 40 percent stiffer than the widely used "E" glass fiber composite and are also superior to composites made with the best commercial "S" glass. Other new glasses offer the potential for a 70 percent improvement in stiffness over the "E" glass composites.

Graphite Fluoride—a new compound of carbon and fluorine—promises to be one of our most useful solid lubricants. Produced by the reaction of graphite with gaseous fluorine, it has a crystal structure very much like that of the starting graphite. Unlike graphite, it is white, clean to work with, and has high electrical resistance. It is less sensitive to environment than molybdenum disulfide or graphite, lubricating almost equally well in moist air, dry air, and dry argon. Preliminary tests at the Lewis Research Center, using burnishing as the technique for applying the dry films, indicate friction coefficients at least as low as those obtained with molybdenum disulfide or graphite and wear-lives which are considerably longer. The use of more sophisticated techniques than burnishing for applying graphite fluoride should increase the service lifetime still further and perhaps solve the problem of producing a trouble-free lubricating film which will last the lifetime of an advanced deep-space mission.

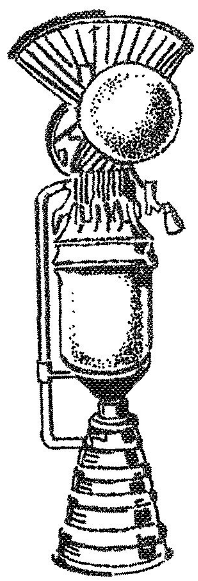
Electrophysics

At the Electronics Research Center, an investigator was able to make barium titanite ($BaTiO_3$) photoconducting by reducing a surface layer with hydrogen to a depth of about 33 microns. Normally, barium titanate is an insulator and is not photosensitive. As a result of the reducing process, the thin surface layer becomes a semiconductor which has high sensitivity to the detection of radiation, especially in the ultraviolet range. Since barium titanate is a ceramic unaffected by relatively high temperatures, it may be used in environments destructive to ordinary photosensitive detectors.

At the Lewis Research Center, an important advance was made in work on plasma thrusters and power conversion devices. In these devices, the working fluid is an ionized gas whose dynamic temperature far exceeds that of the confining walls. Thus, from the

plasma to the walls there is a continuous flux of energy which must be known to maintain the plasma at a desired temperature and to protect the walls against destruction. The determination of energy fluxes from plasmas to confining surfaces is difficult because of complex combinations of heat transfer parameters due to the presence of ions, electrons, excited atoms, and electromagnetic radiation, and because of the continuous reactions of the gaseous constituents with each other.

The theoretical work at Lewis indicated that up to 100,000° K, radiation is the dominant factor for energy transport to the walls. Above that temperature, charged particles dominate in carrying energy away from the plasma to the walls. This knowledge is important for use in the engineering design of plasma type accelerators and power converters.



5 THE NUCLEAR ROCKET PROGRAM

The joint NASA/AEC nuclear rocket program has as its major objective the development of a 75,000-pound thrust nuclear rocket engine, NERVA, for space flight missions. In future space activities, as delineated in the report of the President's Space Task Group, NERVA, employed in a reusable nuclear stage, would offer a new capability for economical space transportation. This stage will be used to move men, spacecraft, and supplies between earth orbit and lunar orbit; between low earth orbit and geosynchronous orbit; and for other deep space activities. Because of the high performance capability of the nuclear rocket, it should offer economy of operation either in single use or reuse mode of operations.

In addition to the engine development activity, the program also includes a variety of supporting and advanced research and technology activities. The objectives of these activities are to extend the basic technology of nuclear rockets, to provide for the continued improvement of nuclear rocket performance, and to provide the base of information for the development of a nuclear stage.

NUCLEAR ROCKET TECHNOLOGY

The development of the NERVA engine relies on technology stemming from more than 15 years of research, testing, and anal-

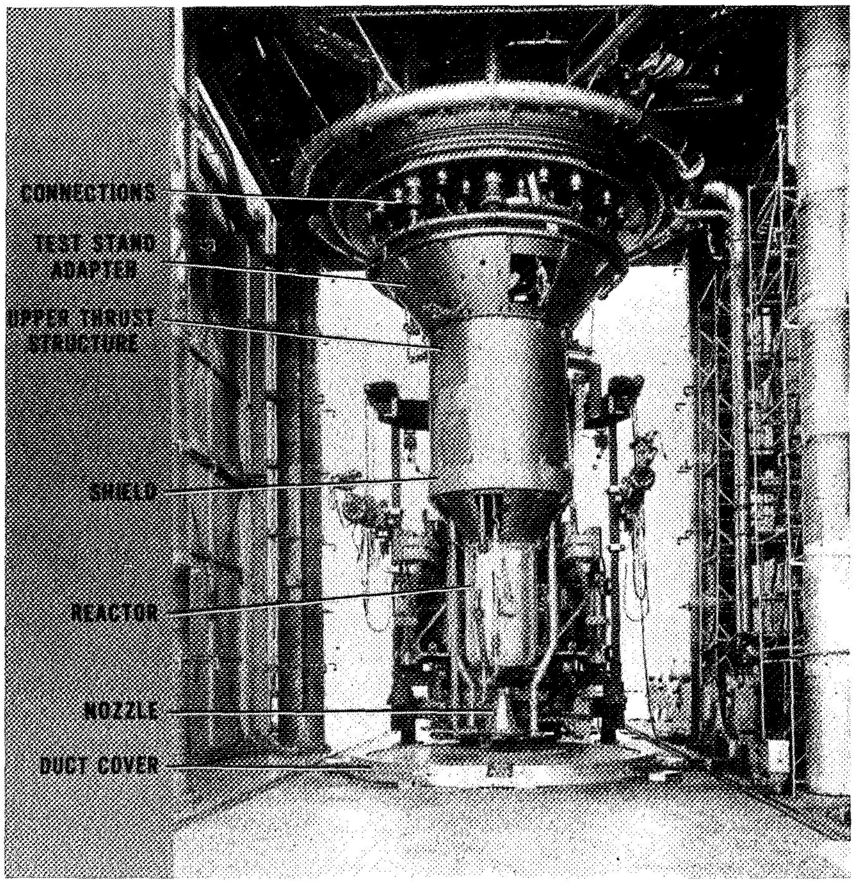


Figure 5–1. Ground Experimental Engine in ETS–1.

yses. This technology program was completed in 1969. Since 1964, when the first nuclear rocket reactor was operated at 1,000 megawatts, 12 consecutive reactors and engines have been tested, providing more than 14 hours of experience at power, and approximately 4 hours of the total at high power. In the course of these tests and other associated work, all of the reactor and engine system technology goals were met or exceeded, and a sound basis was established for proceeding with the design and development of a high-performance, highly reliable engine system for mission use.

Ground-Experimental Engine Test Program

The activity which completed the technology phase of the nu-

clear rocket program in August was the testing, in Engine Test Stand No. 1, (ETS–1) of the ground-experimental engine (XE) (fig. 5–1). The engine was operated during a period of about 5 months for a total operating time of 3.8 hours at various power levels of which approximately 3.5 minutes were at full throttle (about 55,000 pounds of thrust). Twenty-eight separate engine tests were conducted. Engine startup was explored under widely varying conditions, and the engine was operated over the entire range of possible operating conditions. Important data and experience also were obtained about the operation of the engine in the complex facility required for testing. With the completion of these tests, the technology base required for developing the NERVA flight engine was ready.

NERVA DEVELOPMENT

The NERVA engine is being designed as a throttleable, restartable, reusable system that can be used over a long period of time for a number of missions. Engine thrust will be 75,000 pounds at a specific impulse of 825 seconds, and the goal is to achieve an engine capable of operating for many cycles with an endurance goal of up to 10 hours. The engine and stage will be man-rated, with appropriate shielding to protect engine and stage hardware, propellants, and astronauts. It will be ground transportable and storable in ground and launch environments.

The emphasis during this period in NERVA development was on the preliminary engine design, based on a systems engineering approach (fig. 5–2). Design selections included a dual turbopump and redundant piping to increase engine reliability; an electric actuator drive system for reactor control; and an uncooled nozzle skirt. The full flow turbine drive cycle, in which all of the propellant flow passes through the engine turbine to drive the pump and then through the reactor before being exhausted, was also selected.

In the NERVA reactor work, the emphasis was on the reactor structural design, reflector configuration, control system, and the design of reactor core components to meet engine operating requirements. The next step in the program will be to complete the design of these and other engine components and to move into the component development phase.

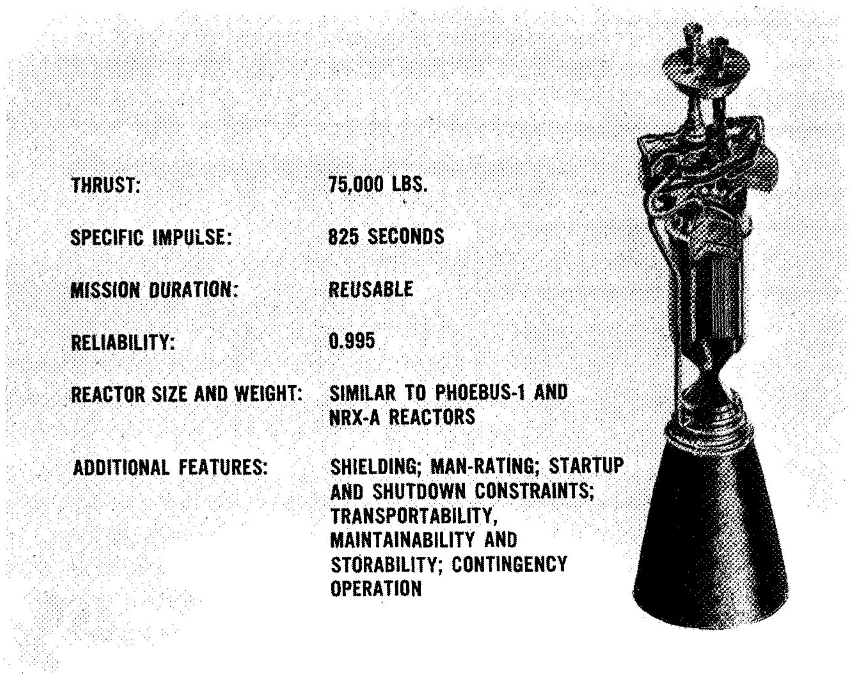


Figure 5–2. Primary NERVA engine requirements.

FACILITIES

In addition to the NERVA development work, preliminary planning and analyses were continued to define the facility requirements for NERVA reactor and engine system development tests at the Nuclear Rocket Development Station in Nevada. Test Cell "C" will be used for all NERVA reactor tests; only minor modifications (to the propellant feed system and interface plumbing) will be required. The NERVA engine will be tested in ETS–1, where several modifications will be made to accommodate this test program. The design of these modifications, which will affect principally the hot-hydrogen exhaust system and the propellant plumbing, has been underway for about a year.

A preliminary study also was conducted for the design and construction of a new engine/stage test stand (E/STS–2) to test the NERVA powered nuclear stage. It will be adjacent to ETS–1 to facilitate the common usage of cryogenic and gaseous fluids.

SUPPORTING RESEARCH AND TECHNOLOGY

Fuel Element Research

The continuing objective of fuel element research is to extend the capabilities of nuclear rocket reactors through the development of improved fuel elements and other core components. The program for improving fuel elements has two principal activities: the development of corrosion resistant coatings for fueled graphite and graphite-carbide composite materials, and the investigation of all carbide fuel elements. The continued strong effort in fuel technology more than doubled the duration capability of nuclear rocket reactor fuel elements, and, in addition, improved the multiple recycling capability. The major reasons for the improvement were the development of better fuel matrices and superior coatings. Both the coatings and their application processes were enhanced, making them more compatible with thermal cycling.

These elements underwent extensive hot-gas testing and at period's end were in production for inclusion in the Pewee-2 reactor scheduled for testing in the winter of 1970–71. Research also was initiated on even more advanced fuel materials which appear to exhibit excellent high temperature performance and resistance to corrosion and show promise of greatly extending the endurance capability of nuclear rocket reactors. A few elements of this type may be tested in the first nuclear furnace in mid-1971. Work also was started to define the effect of fuel-element matrix composition, fabrication techniques, and shape on fuel element performance, particularly at high temperatures.

Vehicle Technology

The vehicle technology effort is directed toward providing design information to support the development of nuclear rocket vehicles for flight applications. Since the technology required for a nuclear rocket stage is largely the same as that for a cyrogenic chemical rocket stage, the stage work sponsored by the program is focused on the problems unique to nuclear propulsion and nuclear rocket missions. These problems relate primarily to radiation effects, propellant heating, and liquid hydrogen storage.

A technology program has been underway at the Marshall Space Flight Center for a number of years, concentrating mainly on radiation-effects testing and propellant heating analyses and experiments. These investigations have been extended to encompass stage operations involving multihour exposures to full-power en-

gine radiation and extended times in space. Although these conditions do not generate critical new problems, they do require reexamination and the extension of existing technology results.

Nuclear Flight Stage Definition Studies

Nuclear stage definition studies were started in this period to determine a basic stage configuration suitable for a wide variety of mission applications, both manned and unmanned. Under consideration in these studies are the uses of a nuclear stage as the upper stage of a Saturn V, as an orbit-to-orbit shuttle, and as a primary propulsion-system for missions deep into space. Study areas include the problems associated with the long-term storage of liquid hydrogen; shielding requirements; meteoroid protection devices; maintenance requirements; and stage design, development, and test plans.

Preliminary information from these studies indicates that the NERVA nuclear powered stage on top of a Saturn V would have a gross weight of between 350,000 and 400,000 pounds, a diameter of about 33 feet, and a length of approximately 150 feet. Stage weight includes allowances for shielding, propellant, meteoroid protection, and the like.

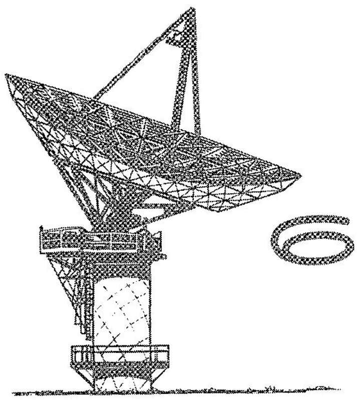
An alternative concept is also being examined, based on its compatibility with the earth orbit shuttle cargo capacity, i.e., tank dimensions of about 15 feet diameter by 60 feet in length. This design approach will result in a nuclear stage consisting of clusters of tanks with a volume equivalent to that of a large tank.

Stage definition studies will continue through June 1971 to provide the necessary information for mission planning and for guiding NERVA development and stage technology activities.

Advanced Nuclear Concepts

While the NERVA class of nuclear rocket will be the first type of nuclear rocket to be used, exploratory research is underway on an even higher performance nuclear rocket concept. This is the so-called cavity reactor in which the nuclear fission reaction takes place in the fluid state, such as a gas, rather than a solid fuel element. An example of the type of problem involved in such a concept is the hydrogen propellant which flows through the reactor cavity at high velocity. It must be separated from the nuclear fuel either by a transparent high temperature wall or by fluid dynamic forces so that the nuclear fuel is not swept out with the propellant.

Theoretically such a concept has a specific impulse performance potential several times that of the solid core. However, the pressures and temperatures of such a system present formidable engineering problems. Feasibility of such propulsion systems is the subject of the research being conducted.



TRACKING AND DATA ACQUISITION

The NASA tracking and data acquisition networks continued to carry a substantial workload. They supported more than 50 NASA-launched missions, 11 of which occurred during this period. The major ones included Apollo 11 and 12, Orbiting Solar Observatory (OSO) 6, Applications Technology Satellite (ATS) 5, and ESRO–1B, a cooperative project of NASA and the European space research organization.

Apollo 11 was the highlight of the reporting period, and the many years spent in constructing and equipping the Manned Space Flight Network to support the lunar landing mission proved worthwhile during this flight. In addition to providing the accurate tracking and communications support necessary to insure astronaut safety, the network enabled hundreds of millions of persons to share, via live television, in that historic venture.

Also during the period, the Deep Space Network supported the encounter phases of Mars by the highly successful Mariner 6 and 7 missions, launched February 25 and March 27, 1969, respectively. The preliminary analysis of the scientific data acquired from the twin spacecraft has significantly enhanced man's understanding of the atmosphere and surface of Mars.

MANNED SPACE FLIGHT NETWORK

On July 16, the manned space flight network began in-flight support of the Apollo 11 mission. The experience gained supporting the Mercury, Gemini, and previous Apollo missions resulted in a flawless performance by the network facilities and operating personnel. Voice communications were excellent; few persons will

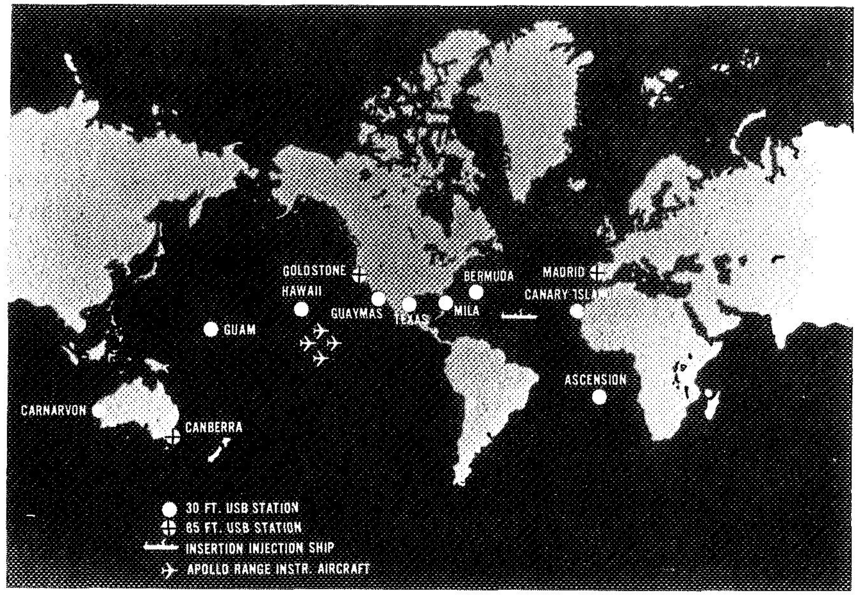


Figure 6–1. Manned Space Flight Network.

ever forget the clarity of Astronaut Armstrong's voice as he said, "Houston, Tranquility Base here. The *Eagle* has landed."

With successful completion of the Nation's objective of landing a man on the moon and returning him safely to earth, the Apollo schedule was revised to a lower launch rate, and the network configuration was reviewed to see if selected reductions in facilities could be achieved without comprising the astronauts' safety. The demonstrated capability of the Apollo launch vehicle and spacecraft to adhere to planned mission timing resulted in a decrease in the previously required support flexibility, and significant changes in the network configuration were possible for the Apollo 12 mission (fig. 6–1). NASA found that only one of the national range tracking ships would be required for Apollo 12 and subsequent missions, and that the requirements for Apollo aircraft could similarly be reduced from eight to four. The reduced geographical coverage requirements also permitted the withdrawal of two 30-foot-diameter antenna land stations, those on Grand Bahama Island and Antigua, from the support of Apollo.

The success of the Apollo 12 mission highlighted the vital role of the network in support of the manned lunar landing program. As

Astronauts Pete Conrad and Alan Bean began their descent to the lunar surface, the network transmitted and received real-time flight control data between the Lunar Module (LM) spacecraft and the Mission Control Center, Houston, Tex. An extremely important portion of these data was a correction to the descent trajectory. The data were fed into the onboard guidance system and corrected the descent trajectory in real-time as the spacecraft headed for the lunar surface. The correction enabled the LM to make a "pin-point" landing in the Ocean of Storms, within about 600 feet of the Surveyor 3 spacecraft.

The network was continuing its support of the Apollo 12 mission by monitoring the Apollo Lunar Surface Experiment Packages (ALSEP) left on the moon's surface. The future lunar landing missions will also carry ALSEP's and will increase significantly the workload on the network.

The network facilities also supported NASA unmanned flight projects and certain missions of other Government agencies (the latter support usually comes during the launch phase of DOD projects such as the Minuteman III and Poseidon vehicle tests.)

NASA COMMUNICATIONS SYSTEM

The NASA Communications System (NASCOM) is a worldwide network of operational lines and facilities which interconnect the mission control centers, launch areas, test sites, and the foreign and domestic tracking stations. It consists of circuits leased from the domestic and international common carriers which include land lines, underseas cable, high frequency radio, and communications satellites. (Fig. 6–2.) The NASCOM provides communications service in support of all NASA flight programs, as well as programs of other agencies as mutually agreed.

During the reporting period, the communications satellite service costs were reduced significantly because of the reconfiguration of the Manned Space Fight Network. As noted earlier, the demonstrated capability of the Apollo spacecraft and the Saturn V launch vehicle permitted the release of all but one instrumentation ship. With the elimination of the Indian and Pacific Ocean ships, communications satellite service and back-up high frequency radio service to these areas were discontinued. Further, the revised Apollo launch schedule permitted the satellite service to the Atlantic Ocean ship to be reduced from full-time to part-time service.

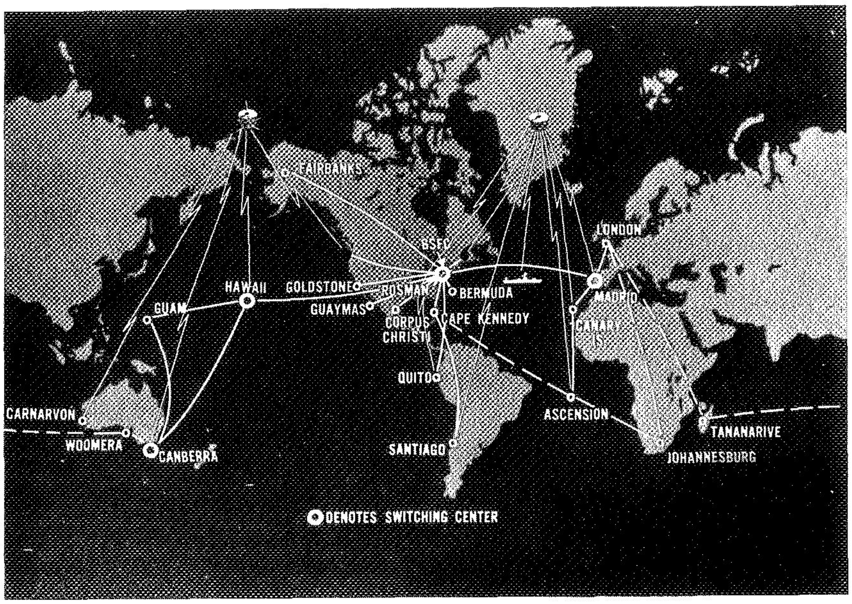


Figure 6–2. NASA Communications Network.

SATELLITE NETWORK

The satellite network continued to support a wide variety of scientific and applications flight programs. In addition to the NASA programs, the network supports the space efforts of other Government agencies, private industry, and foreign governments as well.

The support is provided through the electronic facilities of the Space Tracking and Data Acquisition Network (STADAN), operated under the management of the Goddard Space Flight Center. At the end of the reporting period the STADAN consisted of facilities at 10 U.S. and foreign locations (fig. 6–3) and a centralized control center at the Goddard Center, Greenbelt, Md. The station locations are as follows:

United States	*Foreign Countries*
Fairbanks, Alaska	Canberra, Australia
Goldstone, Calif.	Santiago, Chile
Fort Myers, Fla.	Quito, Ecuador
Rosman, N.C.	Winkfield, England
	Tananarive, Madagascar
	Johannesburg, South Africa

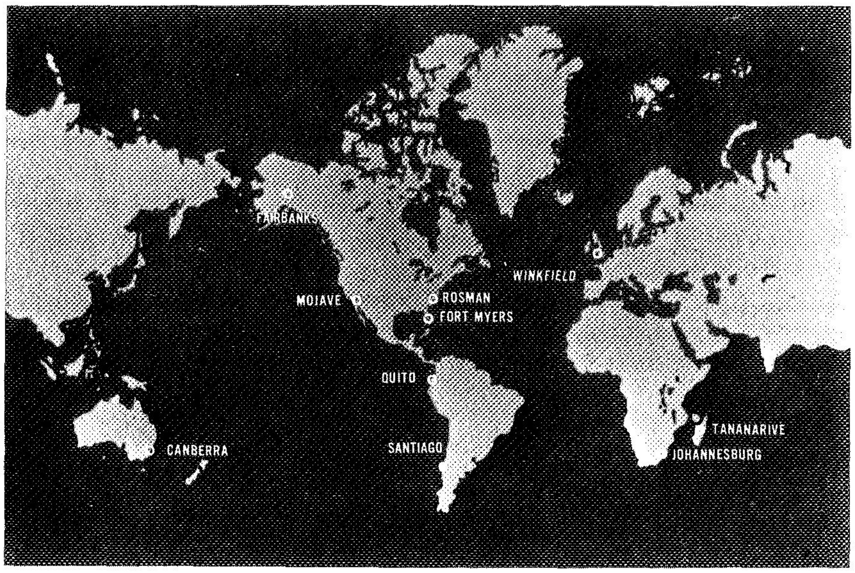


Figure 6–3. Satellite Network.

This list respresents a decrease of three stations from the preceding report period. Changing flight program requirements and substantial budget reductions resulted in station closures at Toowoomba, Australia; St. John's, Newfoundland; and Lima, Peru.

The NASA STADAN stations are supplemented by Baker-Nunn and geodetic camera stations operated by the Smithsonian Astrophysical Observatory. This optical support is financed by a research grant from NASA to the Smithsonian Institution.

The network supported six spacecraft launched during the period and more than 40 satellites launched earlier. The six launches included ATS–5; OSO–6; ESRO–1B, a cooperative project of NASA and the European Space Research Organization; and INTELSAT III F–5, a communications satellite of the ComSat Corp. Also during the period, the network completed its support of the Biosatellite 3 flight. By maintaining constant contact with the spacecraft, the network was able to terminate the mission early when problems arose with the onboard primate. Although the mission was aborted short of its scheduled flight of 1 month, the results obtained were quite important.

Emergency support was required from the network for the Applications Technology Satellite, ATS–5. Shortly after its August 12

launch, the spacecraft developed a malfunction in the onboard stabilization system, requiring a change in the support plan. Under the revised plan, the spacecraft had to be placed into its synchronous orbit at a point where, from the earth, normal coverage was not available. To overcome this lack of geographical coverage, the STADAN station at Johannesburg, South Africa, supported the ATS-5 in conjunction with the previously launched, synchronous ATS-3 satellite. Flight controllers at the Goddard Space Flight Center sent the necessary command signals to the Rosman, N.C., station which relayed them via ATS-3 to Johannesburg and then to ATS-5. The rapid response by the network allowed insertion of ATS-5 into synchronous orbit during its first apogee after launch.

The network provided unique support to the orbiting solar observatory, OSO-6, which carries an experiment to scan small areas of the sun's surface (the data are sent directly to the principal investigator, the Harvard College Observatory, for analysis). If an area of the sun's surface is experiencing unusual activity (solar flares, for instance), the spacecraft can be commanded to scan the selected sector, allowing the experimenters to examine the phenomenon in greater detail. This near real-time command capability of the network significantly increased the scientific data return from the Harvard experiment.

DEEP SPACE NETWORK

The Deep Space Network (fig. 6-4), continued its support of the four on-going Pioneer missions—Pioneers 6, 7, 8, and 9. A major highlight during the period was the network's support of the encounter phase of the highly successful Mariner '69 mission. This mission marked the United States' first dual-flight scientific exploration of another planet. The network monitored and controlled the twin spacecraft, Mariners 6 and 7, from lift-off through their flyby encounter of the planet Mars.

Following the launch phase of the flights, the spacecraft were tracked by stations of the network located on four continents. The stations assigned to the Mariner missions are in Goldstone, Calif.; Woomera, Australia; Madrid, Spain; and Johannesburg, South Africa. The Space Flight Operations Facility (SFOF) located at the Jet Propulsion Laboratory, Pasadena, Calif., maintained centralized control of the missions.

The continuous command and control capability of the network enabled Mariners 6 and 7 to come within 150 and 190 miles, re-

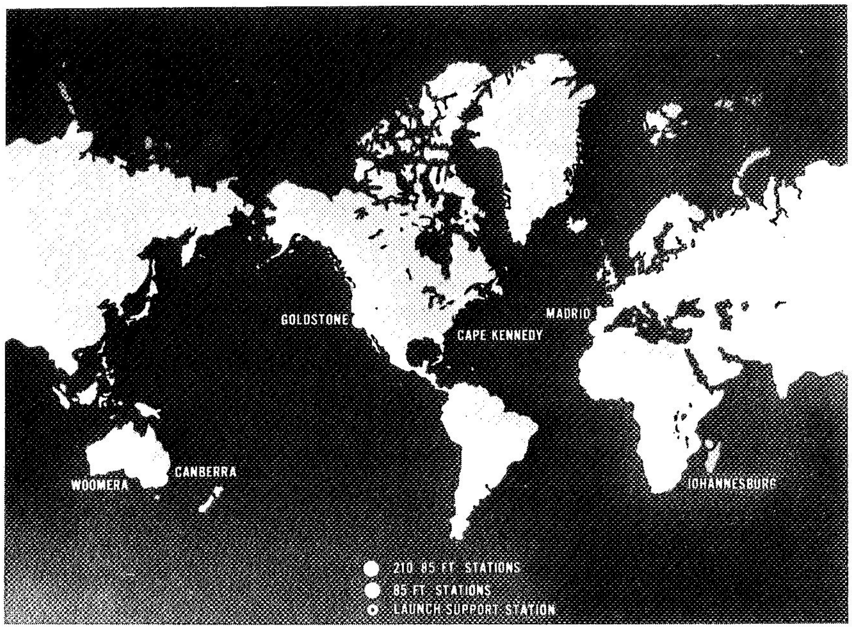


Figure 6–4. Deep Space Network.

spectively, of their targeted points after traveling nearly 190,000,000 miles—an accuracy of one part in one million.

A new high-rate telemetry system—16,200 bits per second—aboard the Mariner spacecraft and the 210-foot-diameter antenna at Goldstone enabled NASA to acquire a large number of approach, or far encounter, pictures. Mariner 6 took 50 such pictures, providing full planet coverage during two revolutions of Mars. Mariner 7 took 93 far encounter pictures, recording the changing view of Mars during three revolutions of the planet. As the twin spacecraft neared the planet, 57 high and medium resolution views of selected Martian surface areas were obtained.

All 200 television pictures acquired from the two Mariners were displayed on TV monitors at JPL as they were received from the spacecraft. This was made possible by the high-rate telemetry system, the 210-foot antenna, and a microwave link from Goldstone to JPL.

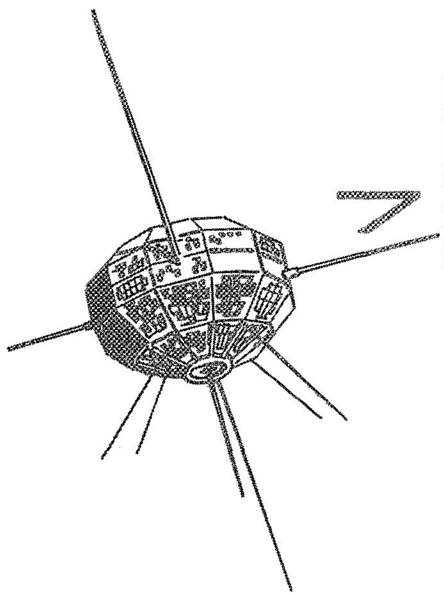
A mission failure nearly occurred on July 30. The Johannesburg station reported loss of signal from Mariner 7 just seven hours before Mariner 6 was to encounter Mars. Flight controllers at JPL believed, though the cause is still uncertain, that the spacecraft was

struck by a meteoroid. As the earth turned under the spacecraft and Mariner 6 neared Mars, the Goldstone tracking stations came into view. Just minutes after Mariner 6 encountered Mars, an 85-foot antenna station at Goldstone picked up a faint signal from Mariner 7. Commands were sent from control center at JPL to Mariner 7 to switch antennas and 11 minutes later—round trip light time between Earth and the speeding spacecraft—a healthy signal was detected by stations at Goldstone and in Australia.

Controllers learned that Mariner 7 had lost lock with its celestial reference, the star Canopus, and the high-gain antenna no longer pointed at earth. The corrective commands carried by the network stations instructed the spacecraft to reestablish Canopus lock, and a near failure was averted.

In addition to its continuous command and control capability, the Deep Space Network provided the means to conduct two experiments during the mission which required no special instrumentation aboard the spacecraft. One was an occultation experiment which provided atmospheric pressure measurements of Mars through the analysis of changes in the spacecraft radio signal as the spacecraft disappeared behind the planet relative to earth. The second experiment dealt with celestial mechanics: by analyzing 3 months of tracking data from Mariners 6 and 7, investigators determined that the mass of Mars is about one-tenth that of earth. The only other precise determination of the mass was obtained from the Mariner 4 (1964) Doppler data. A reexamination of these data indicated that the 1964 and 1969 missions agreed very well in their determination of the planet's mass.

The network will participate in an experiment that will be conducted this spring when the Mariner spacecraft passes behind the sun relative to the earth. At that time, the spacecraft, which will be some 230 million miles from earth, will provide an excellent opportunity to test experimentally Einstein's General Theory of Relativity. By using the capability afforded by the Goldstone 210-foot antenna it should be possible to measure the degree to which the spacecraft radio transmissions are distorted by the gravitational forces of the sun. The expected sensitivity of the measurements will permit, for the first time, a positive confirmation of certain aspects of Einstein's Theory.



7 INTERNATIONAL AFFAIRS

In preparation for the second decade of international space cooperation, NASA began to expand into new areas of activity in the last half of 1969. For example, it took steps to encourage international interests in joint planning for and possible participation in the post-Apollo space flight programs of the 1970's. It reached an agreement with India regarding that country's use of the NASA Applications Technology Satellite (ATS–F) for experimental instructional television broadcasting. And in addition, the Agency made a number of changes in its tracking station networks abroad.

COOPERATIVE PROJECTS

The broad NASA international program of the 1960's in which shared-cost cooperative projects with 37 countries were developed continued. Two foreign scientific satellites were launched. Lunar sample material returned in the Apollo program was distributed to 39 foreign principal investigators. The first agreement to launch a foreign domestic communications satellite was concluded with Canada. Two new foreign experiments were selected for flight on NASA satellites, while two such experiments, selected earlier, were flown in Orbiting Solar Observatory VI. And a number of actions were taken in support of the President's remarks to the U.N. General Assembly on September 18, regarding the potential benefits to be derived from earth resources survey techniques.

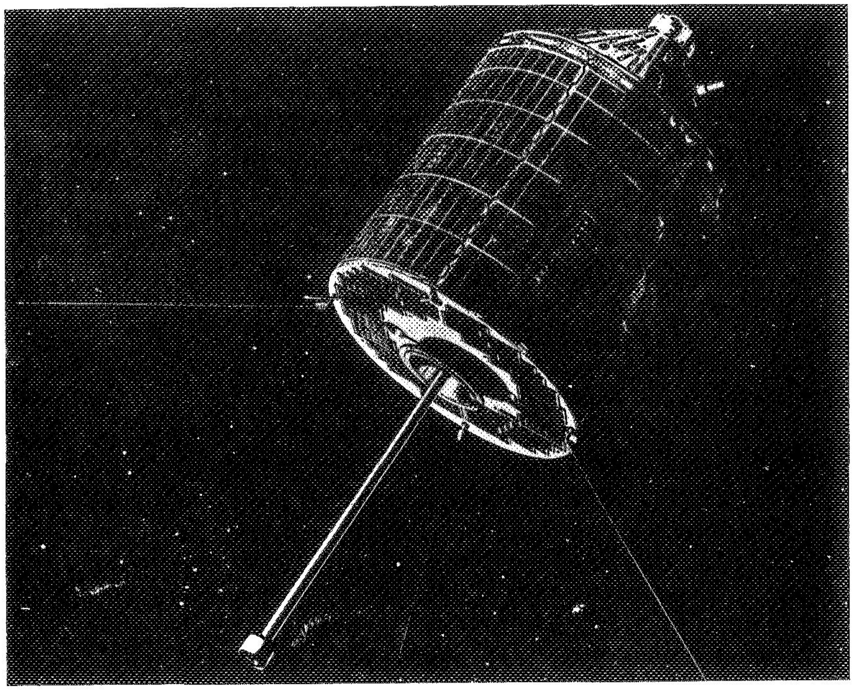


Figure 7–1. Concept of AZUR in orbit.

Canada

NASA agreed with the Tesat Canada Corp. to provide reimbursable launching services for a domestic communications satellite system. The initial satellite in the system is scheduled for launching in 1972.

France

A French experiment for investigating the fine structure of the solar chromosphere was selected for flight on Orbiting Solar Observatory I. This is the sixth experiment from France to be selected in the NASA scientific program.

Germany

AZUR, the first cooperative satellite with Germany, was successfully launched from the Western Test Range on November 7 on a NASA Scout vehicle (fig. 7–1). The eight experiments on board have been collecting data on the earth's radiation belts. Progress continued on three other cooprative satellite projects

with Germany: the barium ion cloud probe to be launched in late 1970; the Aeros satellite to be launched in 1972 to conduct aeronomy studies; and the Helios Project to launch two probes to conduct interplanetary and solar physics studies in 1974–75.

India

NASA and India signed a Memorandum of Understanding on September 18, setting the stage for Indian use of the NASA ATS–F satellite to transmit instructional television (ITV) programs directly to augmented receivers in approximately 2,000 Indian villages. An additional 3,000 villages will have conventional TV sets which will receive the programs via small ground relay stations. NASA's principal contribution will be to make the ATS available for the 1-year period of the experiment in 1973–74. India is responsible for the ground-segment hardware and for the programing. The programs will be directed primarily to family planning, improved agricultural practices, and national integration.

United Kingdom

NASA reached an agreement with the UK Ministry of Technology to continue cooperation in runway tire traction studies. This project, following successful studies at Wallops Island in 1968, provides for testing runway surfaces in the UK to determine, under wet and dry conditions, the correlation between aircraft and ground vehicle braking, and to compare friction readings for eight typical runway surfaces.

Advanced cooperative work in the meteorological satellite area continued, with the selection of a British experiment to investigate upper atmosphere temperature using carbon dioxide radiometry. Scheduled for flight on the Nimbus F satellite, this is the 13th British experiment to be selected for flight on a NASA spacecraft.

ESRO

The tempo of NASA/ESRO collaboration increased during this period. The ESRO–1B scientific spacecraft was successfully launched (on a reimbursable basis) from the Western Test Range (fig. 7–2). Negotiations began for ESRO to purchase three more scientific spacecraft launchings in 1971–72. The two agencies made further progress in developing mission specifications for a possible cooperative experimental air traffic control satellite to serve the US (FAA) and European air traffic control agencies.

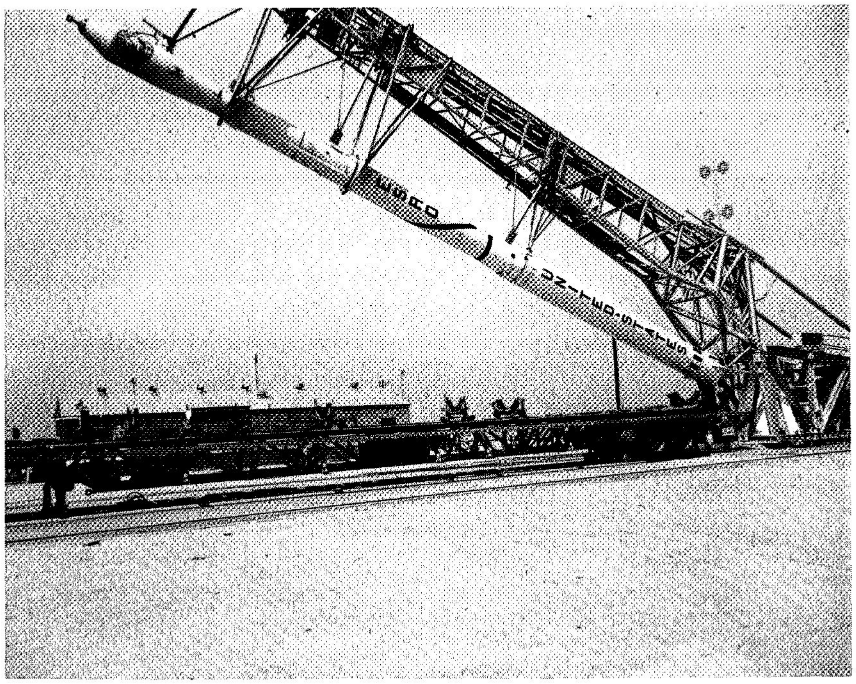


Figure 7–2. ESRO–1B being prepared for launch.

Manned Space Flight Planning for the 1970's

In the last half of 1969, the Administrator visited European and Canadian space officials to explain the major elements of NASA's planning for the post-Apollo program. Foreign officials were invited to assess the plans with an eye toward their own programs as well as toward participation in future US programs.

Following the Administrator's visits, a number of foreign space organizations took steps to become more closely acquainted with NASA's post-Apollo planning and showed interest in exploring possibilities for joint projects.

Lunar Sample Program

Lunar samples from the initial Apollo lunar landing missions were distributed to 39 foreign principal investigators from nine countries. In addition, 16 new foreign proposals were recommended for approval to receive samples returned from Apollo 13. This new participation would involve seven additional countries, bringing the total to 16. The initial nine countries whose scientists

are participating in the program are Australia, Belgium, Canada, Finland, Germany, Japan, South Africa, Switzerland, and the United Kingdom. Newly added are investigators from Czechoslovakia, France, India, Italy, Korea, Norway, and Spain.

Earth Resources Survey

On September 18, President Nixon drew world attention to the potential benefits of earth resources survey techniques in an address to the U.N. General Assembly. He stated that the US would share the projected benefits of the program as it proceeds and fulfills its promise. In support of these objectives, NASA continued its cooperative remote sensing aircraft programs with Brazil and Mexico and provided advice to India on the establishment of an Indian program.

The Agency supported the International Biological Program with earth resources aircraft data and expanded its International Graduate Fellowship Program to include earth resource disciplines. NASA also called the attention of U.N. member states to the Sixth International Symposium on Remote Sensing of the Environment, held at the University of Michigan in October. Personnel from NASA, the Department of Interior (USGS), and the Department of Agriculture participated in a number of earth resources symposia abroad. Additionally, the US collaborated with India in efforts to establish a liaison office for space applications in the U.N. Secretariat.

Airborne Auroral Expedition

The Airborne Auroral Expedition 1969, using NASA's instrumented jet aircraft, conducted 14 flights during November and December to study auroral phenomena in northern latitudes. Flights took place over Canada, the Greenland Sea, and the Arctic Ocean, with the aircraft staging at Fort Churchill, Manitoba, in November, and at Bodo, Norway, in December. French and Canadian scientists participated with experiments, and Norwegian observers were aboard some of the flights.

Cooperative Sounding Rocket Programs

NASA made two new agreements for cooperative sounding rockets. It signed a Memorandum of Understanding with the Royal Norwegian Council for Scientific and Industrial Research to carry out auroral studies on NASA rockets from Andoya, Norway. Also, the Agency arrived at a tripartite agreement which provides for

Pakistani and UK atmospheric research payloads to be flown on NASA rockets from Sonmiani Range, Pakistan. Sounding rocket flights continued from ranges in Argentina, Brazil, Canada, and India under earlier agreements.

UNITED NATIONS

The Administrator briefed the U.N. Committee on the Peaceful Uses of Outer Space on the results of the Apollo 11 mission during the Committee's 12th session in New York in September. The Assistant Administrator for International Affairs served as Alternate US Representative during the September meetings.

OPERATIONS SUPPORT

NASA made a number of changes in its tracking station networks as a result of shifting program requirements.

The Grand Bahamas and Antigua manned flight stations were placed in a caretaker status. In the STADAN network, the Lima, Peru, station was deactivated, and the Newfoundland, Canada, station is to be phased out by the end of March 1970. The optical tracking station being operated for NASA by the Smithsonian Astophysical Observatory at Commodoro Rivadavia, Argentina, was closed, and other changes in the optical network were under consideration.

Although the Cooby Creek, Australia, Applications Technology Satellite station ceased supporting NASA experiments in September, Australia is making temporary use of the station for its own experiments. Negotiations with that country are under way for a 10-year extension of the existing tracking station agreement and for the establishment and operation of a 210-foot diameter antenna to be located near Canberra to support forthcoming planetary programs.

NASA agreed with representatives of Canada that the intergovernmental agreement of June 11, 1965, concerning the joint US-Canadian support and use of the Research Range, Fort Churchill, Manitoba, will be permitted to expire on June 30, 1970. Canada intends to maintain the Range in a reduced status. Any future United States use of the rocket launching and scientific research facilities at the Range will probably be on a reimbursable basis.

Australia's 210-foot radio astronomy antenna at Parkes, Australia, supported Apollo 11 and 12 during lunar module descent and astronaut activity on the Moon.

PERSONNEL EXCHANGES, EDUCATION, and TRAINING

During the second half of 1969, 2,900 foreign nationals from 103 locations visited NASA facilities for scientific and technical discussions or general orientation.

Under the NASA International University Fellowship Program, 56 students from 14 nations were engaged in graduate study at 21 American universities. They were supported by their national space research sponsors or by ESRO. This program is administered for NASA by the National Academy of Sciences.

One hundred and three postdoctoral and senior postdoctoral associates from 19 nations carried on advanced research at NASA centers, including the Jet Propulsion Laboratory. This program, also administered by the National Academy of Sciences, is open to both US and foreign nationals.

Eighty-two scientists, engineers, and technicians from Australia, Canada, Germany, India, Italy, Japan, and Spain—here at their own expense—received training in space technology at the Ames Research Center, the Goddard Space Flight Center, and Wallops Station in connection with cooperative projects.

8 UNIVERSITY PROGRAMS

NASA's university project research is aimed at meeting the research needs of NASA program offices and field centers. It is supplemented by the Sustaining University Program, which supports multidisciplinary research and other university activities important to NASA's mission but broader in scope than most program office research efforts. All elements of the NASA university program are developed and administered so as to provide maximum benefit to NASA and at the same time strengthen the participating universities.

SUSTAINING UNIVERSITY PROGRAM

Sustaining University Program grants to universities allow considerable local control over the selection of specific research tasks. Grants for research are step funded. Other activities, including training, are full funded.

Multidisciplinary Research

The Sustaining University Program provides support for special research programs developed in response to problems vitally affecting the Nation's leadership in aeronautics and space.

The multidisciplinary research grant program has made it possible for space science and engineering centers to be established at a

number of universities. It has also promoted coordination between university research centers and NASA laboratories, by enabling faculty members to visit the NASA research centers and by permitting some university students to conduct research with the unique and specialized research equipment at the NASA laboratories.

During this period, the Sustaining University Program had active multidisciplinary research grants at 55 universities, and awarded grant supplements at the following universities: University of Alabama, University of Denver, George Washington University, University of Houston, Louisiana State University, Pennsylvania State University, Purdue University, University of Virginia, Washington University (St. Louis), West Virginia University, and the University of Wisconsin. The grants provided research support for 600 faculty members and an equal number of students.

The Sustaining University Program continued its efforts to identify research capabilities of value to the national space program at predominantly Negro colleges and universities near NASA field centers. Twelve such institutions were awarded research grants averaging about $20,000: Alabama A. & M. College, Alabama; Tuskegee Institute, Alabama; Oakwood College, Alabama; Talladega College, Alabama; Morgan State College, Maryland; Bowie State College, Maryland; Delaware State College, Delaware; Howard University, Washington, D.C.; Federal City College, Washington, D.C.; Prairie View A. & M. College, Texas; Bishop College, Texas; and the Texas Southern University, Texas.

Administration and Management Research

This program continued to provide support for research and graduate training in the administration and management of large, complex organizations at Syracuse University, the University of Pittsburgh, the University of Southern California, the University of New Mexico, Northwestern University (Graduate School of Management), Drexel Institute of Technology, and the National Academy of Public Administration. A new research program was initiated in the Department of Industrial Engineering and Management Sciences at Northwestern University. NASA provided support for 35 trainees at Syracuse, Pittsburgh, and Southern California which have traineeships in public administration closely integrated with their research programs.

Engineering Systems Design

The third group of 25 trainees in engineering systems design entered the program in September 1969. They were enrolled at Stanford University, Purdue University, Cornell University, the University of Kansas, and Georgia Institute of Technology and were in the process of selecting their projects.

The first group of trainees (entered in September 1967) are in their last year and working on their design dissertations (*21st. Semiannual Report,* p. 162).

Special Training

This category includes the Summer Faculty Fellowship Program, Summer Institutes for talented undergraduates, a post-M.D. effort, and a few predoctoral training grants directly related to the space program (*21st Semiannual Report,* p. 162).

During the summer of 1969, 12 universities and nine NASA centers cooperated in offering research and study opportunities to about 280 faculty members in the research part of the Summer Faculty Fellowship Program. Four 11-week Summer Faculty Fellowship Programs in Engineering Systems Design were conducted by six universities in cooperation with four NASA Centers. About 80 faculty members worked on projects such as a preliminary design of an orbiting space technology applications and research laboratory, a metropolitan air transit system, an operational earth resources survey system, and a manned exploration vehicle. In addition, about 100 senior undergraduates received six weeks of specialized summer training in space science and technology at four universities.

NASA continued to support training in aerospace medicine at Harvard University and Ohio State University, where a few select physicians received advanced training concerned with environmental problems of man in space.

Thirty new predoctoral students under six predoctoral training grants began their studies in specific areas related to the national space program. They will work toward the Ph. D. in aeronautics and lasers and optics at Stanford University, vibrations and noise at North Carolina State University and the Pennsylvania State University, communications sciences at the University of Southern California, and international studies in space science and technology at the University of Miami.

Resident Research Associateship Program

This program, administered for NASA by the National Research Council—National Academy of Sciences—National Academy of Engineering, is designed to allow postdoctoral and senior postdoctoral investigators to carry on advanced research at NASA field centers. Participants conducted research in fields such as astrophysics, airglow emission, high-energy physics, geomagnetism, instrumentation for direct atmospheric measurement, applied mathematics, electron microscope, comparative biochemistry, hypersonic aerodynamics, plasma flow, materials, and meteorites. Scientists in this program were distributed among NASA centers as follows:

Center		*Participants*
Goddard Space Flight Center		65
Greenbelt, Md	44	
Institute for Space Studies, N.Y	21	
Ames Research Center		42
Marshall Space Flight Center		12
Langley Research Center		10
Manned Spacecraft Center		13
Jet Propulsion Laboratory		24
Electronics Research Center		9
Total		175

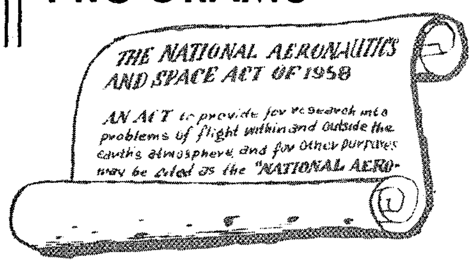
Research Facilities

Additional structures for the University of Washington and the Lunar Science Institute were completed and occupied, bringing to 36 the number of completed buildings providing nearly 1⅕ million gross square feet of space on university campuses. The space is enough to accommodate some 3,900 university scientists, engineers, and others engaged in research in aerospace science and technology. The remaining structure in this program at the University of Kansas is about 50 percent complete.

Research Grants and Contracts

The Office of University Affairs received 1,152 proposals and 615 were funded (*21st Semiannual Report*, p. 165). Special step-funding efforts were being phased to completion, as the office applied $1 million to add step-funding to 25 additional grants. NASA now has nearly 40 percent of its active project grants on a stable funding basis.

9 INFORMATIONAL AND EDUCATIONAL PROGRAMS



The National Aeronautics and Space Act of 1958, in creating NASA, stipulated that it should "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." During the past decade the Agency has carried out this congressional mandate through varied, continuing informational and educational programs.

Informational Activities

Public Affairs activities for 1969 actually began with the Apollo 8 lunar flight in the preceding December. Heavy news media coverage of that event and the rollout a week later of Apollo 9, in addition to White House, Congressional, and TV appearances of the Apollo 8 crew, plus parades for them in Washington, New York, Miami, Houston, and Chicago were the responsibility of the Office of Public Affairs.

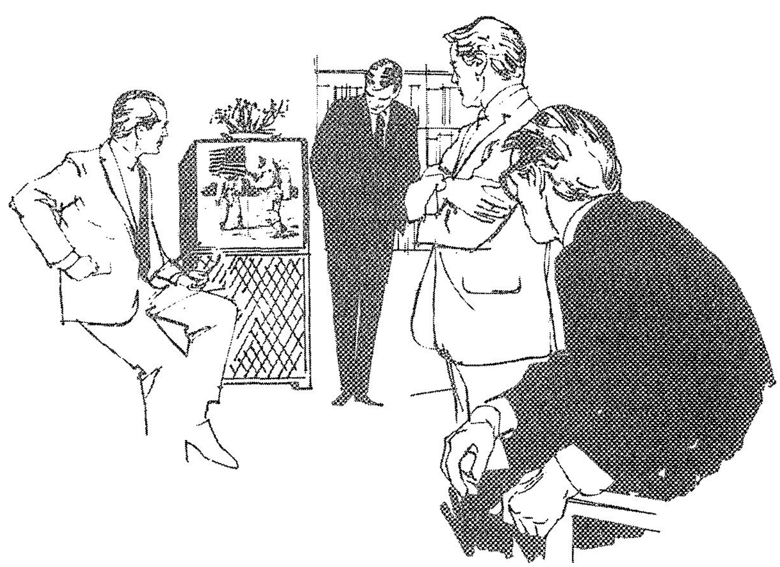
Media Services

In addition to the manned launches of Apollo 9, 10, 11, and 12 in 1969, Public Affairs supported 18 other major flight missions,

preparing press kits which gave background information, hardware descriptions, mission profiles, experimental techniques, results expected, names of experimenters, and contractors. Most launches also included a premission briefing and question and answer session for the press, a press tour of the launch area, the provision of communication and observation facilities for the launch, a post-launch briefing, and a mission results news conference. Press kits were mailed to 614 daily newspapers on request, 1.16 million still photos to the news media and to book publishers, prelaunch clips to 700 requesting TV stations, and radio spots to as many as 2,500 requesting radio stations.

For all of 1969, NASA issued 1,606 news releases, 104 radio features, 12 five-minute monthly television news programs, and 360 television news clips. In addition to the news releases, 954 requesting newspapers were supplied with a total of 26 narrative and pictorial features, in 8-column newspaper format. Subscribing newspapers estimated their circulation at 61 million.

The launch of Apollo 9 on March 3, and of Apollo 10 on May 18, further prepared the Public Affairs staff for the work-load created by Apollo 11—the most-watched planned event of all time. As the tables below show, the number of press, public, and invited visitors accommodated increased significantly with each succeeding launch, imposing an increasing load on the limited number of Public Affairs personnel available.



Media Accreditation—Apollo Manned Launches:

Apollo	Total Domestic & Foreign	Foreign Correspondents	Foreign Countries
7	646	26	11
8	1,500	200	24
9	1,403	63	13
10	1,519	230	25
11	3,497	812	56
12	2,262	388	53
13	1,665	370	25

Visitors at Apollo Manned Launches—KSC

Apollo	Invitations	Acceptances	(Est.) Dependents	Gen. Public* Surrounding Area
7	2,041	1,165	2,080	100,000
8	3,125	2,145	3,200	250,000
9	2,673	1,338	2,000	190,000
10	6,500	3,200	4,000	300,000
11	12,300	7,500**	7,974	800,000
12	7,500	4,854	5,527	250,000
13	8,000	5,146	17,700***	500,000

* Newspaper estimates.
** Distinguished guests—including Congressional and International—broke all previous records.
*** North Parkway Site opened to KSC dependents (NASA & Contractor).
Estimates: 10,000 dependents, 7700 guests.

Figure 9–1. Children view lunar sample.

Exhibits

The Paris Air Show was the major foreign exhibition in which NASA participated in 1969. In addition, the Agency furnished materials or services for such other foreign exhibits as "Man and His World" in Montreal, the "Caribbean Exposition" in Antigua, COSPAR in Prague, and "Challenge of Space" in Australia. Also, plans were made for participation in Expo '70 at Osaka, Japan.

The public affairs staff was also deeply involved in preparing for the presentation of lunar samples, along with national flags carried by the Apollo 11 crew on their lunar journey, to 137 foreign governments. In the United States, NASA exhibits had 683 showings, during which they were viewed by 37,600,000 people. This number does not include those who viewed artifacts such as spacecraft and aircraft (like the X–15) presented to the Smithsonian Institution. Requests for exhibits far exceeded NASA's ability to satisfy them.

Films

In addition to printed materials and exhibits, NASA loaned 84,231 film prints, to schools, civic organizations, and similar groups for viewing by 10 million people. On televison alone, NASA films were broadcast 7,711 times. NASA released 14 films in 1969, and 6 more were in production. Most films are loaned on specific request. They are also available for sale through the National Archives and Records Service; NARS has sold 2,200 prints of the Apollo 11 film "Eagle Has Landed."

Public Inquiries

In 1969, NASA and the astronauts received almost 1 million pieces of mail from the general public, the senders ranging from school children and teachers to serious inventors and foreign citizens. Subject matter of the inquiries included both praise and criticism as well as requests for "all you know about rockets." In addition to individual replies where necessary and feasible, NASA sent inquirers about 5 million copies of publications from its current inventory of 60 pamphlet titles. In addition to the NASA distribution, the Government Printing Office sold half a million copies, and over 600,000 picture sets at a profit to the U.S. Treasury.

As the time of the Apollo 11 launch approached, Public Affairs personnel were mobilized from all centers, and redeployed to Kennedy Space Center, Manned Spacecraft Center, the recovery fleet,

Hawaii, Australia, and Spain. Those in Australia and Spain facilitated real-time release of the Mariner VI and VII photos and at the same time were deeply involved in the activities concerned with the Apollo 11 flight. Coverage by the news media was unprecedented. The television and radio transmissions were probably heard and seen by more people throughout the world than any broadcast before or since. Real-time transmissions were made available to any nation which wished to "plug in." An estimated 650 million people watched the moon walk as it happened—500 million abroad (320 million in West Europe, 75 million in Latin America, and the remainder in Japan and other parts of Asia).

EDUCATIONAL PROGRAMS

Spacemobiles

The Spacemobile program presented lecture-demonstrations to 3 million students and teachers in all states, territories, and 3 foreign countries. Lecturers also appeared before civic groups and television audiences to explain rockets and space exploration. During the summer, the program provided resource personnel and material to 1,326 summer teacher workshops, attended by 62,967 teachers. It also made week-long appearances in 51 cities in support of the Vice President's Summer Space Education Program, under the sponsorship of the President's Council on Youth Opportunity.

Publications and Other Educational Activities

The Educational Programs Division also had underway the preparation and publication of curriculum supplements (not textbooks) in the industrial arts, biology, chemistry, mathematics, physics, and space science. The supplements are designed to allow the individual teacher to introduce new space-related knowledge into the regular curriculum promptly. The Division also responded to school, teacher, and student requests for career guidance information and materials; assisted school and non-school youth groups such as JETS and Boy Scouts, and arranged for NASA engineers and scientists to act as judges at local, regional, and the national Science Fairs.

A NASA-originated student motivational competition was also sponsored. Called the Youth Science Congress, it is conducted by the National Science Teachers Association in 12 regions of the country. In 1969, it attracted 236 students who conducted original

research and delivered papers before other students, first locally and then regionally. In the regions, students visited NASA installations and were paired with scientists or engineers in the same field of interest.

Apollo Activities

In February, Astronaut Borman visited nine European cities on a goodwill mission for the President. Preparations for the tour and support during it were provided by the public affairs staff. Public Affairs also handled the award ceremonies and testimonial functions for the Apollo 8 crew, made arrangements for the Apollo 9 crew appearance at the Paris Air Show in May, and took care of the nation-wide tour of the Apollo 10 crew—New York to Florida, Puerto Rico, Los Angeles, Sacramento, San Francisco, San Diego, and finally the White House—over a 16-day period in June.

The office was also heavily involved in the activities of the Apollo 11 crew: The Houston salute on August 16, the astronauts' hometown celebrations in September, the appearance before a Joint Session of Congress on September 16, the commemorative stamp ceremony September 9, and a 39-day goodwill tour of 23 nations beginning September 29, followed by a two-day visit to Canada, and many other appearances sandwiched in among the major ones.

In addition to appearances by the crews of Apollo 8, 9, 10, and 11, other astronauts made a total of 513 appearances in 1969. Other NASA speakers, all of them speaking strictly as an outgrowth of their main occupations as scientists, engineers, and administrators, gave 2,049 talks to diverse groups. The Administrator delivered 30 of these addresses.

Toward the end of the year, Public Affairs officials participated in reporting on the results of the Mariner missions to Mars, arranged for the showings of the Apollo 11 lunar samples, took part in the press conference on the future Viking program; and handled press coverage of the Apollo 13 rollout at KSC.

All of these activities were part of the effort of the Public Affairs Office to make the space program known to the people. For the 2,636,000 persons who visited NASA installations in 1969, Public Affairs staff members acted as hosts and guides, and gave information in many forms—exhibits, tours, motion pictures, publications, lectures, and demonstrations.

SCIENTIFIC and TECHNICAL INFORMATION

NASA also continued its efforts to promote wider dissemination of data in space science and technology to scientists, engineers, program managers, and others.

NASA/RECON

The NASA/RECON system of remote consoles for on-line computer information retrieval—which become operational in February 1969 with a limited number of remote stations—was expanded into a nationwide network of 22 stations linking Agency installations (*19th* and *20th Semiannual Reports*).

NASA/STIMS

In addition, improvements in the central computer installation at the Agency's Scientific and Technical Information Facility resulted in a substantial increase in direct-access storage capacity and the completion of a new set of flexible computer programs. Coupled with NASA/RECON, this software system—known as NASA/STIMS (for *S*cientific and *T*echnical *I*nformation *M*odular *S*ystem)—provides a real-time interaction between the user, the computer, and the direct-access files of the information base. While the principal information bank stored in the computer has been more or less limited to scientific and technical aerospace reports, papers, documents, and journal articles, the new system will include numerous types of managerial data.

RECON Software Availability

RECON software was made available to the Atomic Energy Commission for adaptation to the AEC technical information system, and through an exchange agreement to the European Space Research Organization. ESRO began operating its RECON system against the NASA-provided information base in mid-1969.

Also, the House Committee on Science and Astronautics arranged with NASA to install a RECON console for its use.

Technical Publications

Numerous scientific and technical publications were released and distributed. Several Special Publications (SP) are listed in appendix N—among them SP–214, *Apollo 11 Preliminary Science Report* (ch. 2, p. 48) and SP–225, *Mariner-Mars 1969: A Preliminary Report.*

Along with its Special Publications, NASA Technical Reports, Technical Notes, Contractor Reports, and Technical Translations were made available around the world to over 2,500 organizations working in fields directly related to or associated with NASA's programs. About two million of these were distributed in printed form and over six million on microfiche. They are also sold to the general public by the Superintendent of Documents, U.S. Government Printing Office, and by the Clearinghouse for Federal Scientific and Technical Information.

User Charges

NASA and the Clearinghouse for Federal Scientific and Technical Information have agreed to extend through June 30, 1970, the experimental application of user charges for paper copies of all unclassified, unlimited NASA and NASA-sponsored documents. Charges apply to individual requests for specific documents after automatic initial distribution has been made. (Automatic initial distribution of NASA publications, and distribution of microfiche and classified or limited documents are not affected by this agreement.)

TECHNOLOGY UTILIZATION

NASA was strengthening and at the same time expanding its program to transfer aerospace-generated technology to users who might apply it to help solve growing national problems in such areas as law enforcement and scientific crime detection, water and air pollution control, and mine safety. The Agency also stepped up the identification of technological innovations developed at its laboratories and at contractor facilities.

New Technology Identification and Reporting

By the end of 1969, over 17,000 potentially valuable innovations had been identified and reported through the Technology Utilization Program. Improvements in the new technology identification and reporting system resulted in an increase in the number of NASA contractors participating during the year.

Regional Dissemination Centers

The NASA-sponsored experimental Regional Dissemination Centers at universities and nonprofit research institutions broadened their information bases by adding data in chemistry, engineering,

electronics, and plastics, and by including Department of Defense unclassified unlimited data. The six Centers also began to market computer software from the COSMIC program.

The Centers also continued to cooperate with other Federal agencies. For example, in cooperation with the Small Business Administration, experimental memberships were provided small firms, and literature searches of Technology Utilization publications were undertaken for small businesses through SBA. In addition, joint conferences and symposia were held with SBA and the Office of State Technical Services of the Department of Commerce.

Technology and Biomedical Applications Teams

Technology Applications Teams—made up of scientists and engineers of various disciplines—at the I.I.T. Research Institute, Chicago, Ill., and the Stanford Research Institute, Menlo Park, Calif., were working with Federal, State, and local government agencies to match problems in air and water pollution, law enforcement and crime detection, weather modification, and mine safety with potential solutions based on technology derived from aerospace research and development.

The three NASA-sponsored Biomedical Application Teams, in a continuing program of identifying and defining significant biomedical problems able to benefit from applications of aerospace-related technology, have worked closely with over 1,000 clinicians and researchers. Greater emphasis was being placed on identifying those problems which present major obstacles to clinical and medical research of national scope and importance. Accordingly, relationships were established with the National Institutes of Health (the National Cancer Institute) and the Health Services and Mental Health Administration (the National Health Services Research and Development Center). The teams also began to work with regional medical societies in the identification of pressing clinical problems.

The COSMIC Program

The Computer Software Management and Information Center (COSMIC) at the University of Georgia has filled over 19,000 orders for nonaerospace users since it was established in 1967. Its 800 computer software packages of documented programs were supplied, on request, to businessmen, industrialists, educators, physicians, and government agencies throughout the United States.

During this period, two steps were taken to increase public awareness of these COSMIC services:

- the Regional Dissemination Centers (p. 156) made the computer software available;
- the computer programs were announced in an indexed *Computer Program Abstracts* journal sold by the Superintendent of Documents, U.S. Government Printing Office.

Interagency Cooperation

In addition to continuing its Technology Utilization programs with the AEC, the Departments of Defense, HEW, Commerce, Interior, and Justice, and the Small Business Administration, NASA, and the Department of Housing and Urban Development were investigating ways of applying aerospace-generated technology and management methods to solve city problems. The Agency was also studying possible applications of this technology to automotive safety under an agreement with the Department of Transportation (*21st Semiannual Report*, p. 169).

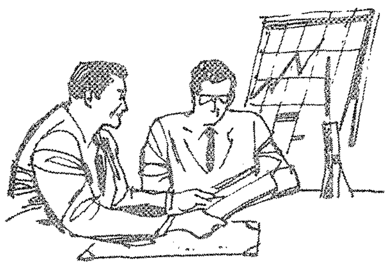
HISTORICAL PROGRAM

Major histories, released as Special Publications during the past 6 months, were *Project Gemini Technology and Operations: A Chronology,* and *The Apollo Spacecraft: A Chronology—vol. 1, Through November 7, 1962* (app. N). In press were *Astronautics and Aeronautics, 1968,* and histories of NASA's Project Vanguard and the Ames Research Center. An integrated series of historical monographs for Project Apollo, and histories of the Ranger, Gemini, Lunar Orbiter, sounding rocket, and tracking network programs were being prepared.

In addition, NASA used counterpart funds, to sponsor the translation of a number of foreign histories of aeronautics and astronautics including some from the U.S.S.R.

The Historical Advisory Committee (app. E) met at NASA Headquarters in May and submitted its recommendations to the Administrator in December. The Committee expressed particular interest in having the account of the U.S. program of lunar exploration fully documented and thoroughly researched because of the unique impact of the first lunar landing on American, and world, history.

10



SUPPORTING ACTIVITIES

During the last half of 1969, NASA continued taking those steps to improve the effectiveness and efficiency of its supporting functions. It emphasized upgrading and making maximum use of its employee's full capabilities. It placed increased stress on its financial management, cost reduction, and procurement functions. It continued to work closely with other government agencies and private industry so the Nation could obtain maximum benefits from all aeronautics and space research results. And it expanded the scope and role of its safety programs.

PERSONNEL

Throughout all its personnel activities, NASA stressed better management-employee relations, including agreements with employee unions and efforts to provide equal opportunities for all of its people. Manpower utilization studies were conducted, and a number of key executive positions were filled by appointment or reassignment. The total effort was aimed at improved efficiency of the work force.

Training Activities

NASA designed, procured, and monitored the development of two new courses of instruction: Systems Engineering (4 weeks, live-in), and Systems Management (3 weeks, live-in). These courses are intended principally for large numbers of engineers, project and program managers, and other selected personnel of NASA Headquarters, Kennedy Space Center, the Manned Space-

craft Center, and the Marshall Space Flight Center. Later, they are to be made available to other Agency elements.

Objective of the instruction is to improve the capabilities of participants in current concepts and techniques of systems engineering and management. NASA expects the training to contribute to increased efficiency and economy of operations and to provide the nucleus for advanced related training. Inclusion of topics in communication and behavioral sciences is also planned to strengthen the supervisory development of enrollees.

Pilot presentations of both courses are to be conducted in January and February, 1970; formal instruction will begin on or about April 1, 1970.

NASA also continued to provide specialized seminars on an Agency-wide basis for program and project teams; such seminars are intended to promote management improvement and uniform treatment of NASA policy where required. During this period, courses in "Effective Use of Reliability Program Outputs in Project Decisions," "Assuring Effectiveness of Contractor Reliability Assurance Programs," and "Supervision and Management in NASA" were conducted for NASA employees. A contract was let to develop a 16-hour course in the basic principles, policies, and procedures of the NASA university affairs program, and one in technical and contractual administration of university programs.

Six NASA Executives attended the CSC Federal Executive Institute, and 23 NASA employees attended various sessions at the CSC Executive Seminar Centers. NASA installations continued their cyclic programs such as academic education, cooperative education, apprentice training, science and engineering lecture programs. They also continued to conduct a wide variety of management and skills training.

Equal Employment Opportunity

NASA revised its regulations and procedures in accordance with the new Executive Order on Equal Employment Opportunity in the Federal Government. Presentations were given to top management officials and supervisors at Headquarters and field installations, explaining the overall NASA program, the Administrator's support for the EEO program, current implementation of the new Equal Employment Opportunity regulations and procedures, and NASA goals for the future.

Manpower Research and Utilization

In November, the Agency initiated a Research Support Occupational Study to obtain detailed occupational information for all Agency positions wherein the occupants are engaged in research support work activities. The study will also develop work category definitions which will readily identify specific skills and fields of knowledge required to perform the Agency's work or mission. The final results of this study should enable personnel officials and line management officials to jointly achieve more economical use of Agency employees assigned to research support positions. The study will be completed in 12 to 18 months.

On October 15, 1969, NASA issued a supplement to the Federal Personnel Manual providing objectives relating to position management programs at NASA Installations. It also sets forth guidelines for the minimum program elements each NASA Installation is expected to follow.

Employee-Management Cooperation

A new 2-year agreement was negotiated between the Langley Research Center and the Pattern Makers Association of Newport News and Vicinity. It covers all modelmakers, technicians, and apprenticies assigned to the Composite Model Development, Pliant Model Development, and Dynamic Model Development Sections of the Office of Engineering and Technical Services. The Center also concluded negotiations with the International Association of Machinists and Aero-Space Workers, and their collective bargaining agreement was undergoing review for approval by the NASA Administrator at period's end.

Local 2182 of the American Federation of Government Employees requested the Director, Lewis Research Center to give exclusive recognition for a unit of 20 fire fighters. The request was denied on the grounds that the unit was not an appropriate one. An appeal was filed by the national office of the American Federation of Government Employees. The NASA Administrator requested the Secretary of Labor to appoint an arbitrator in connection with this unit determination. An arbitrator was selected, and he scheduled a hearing for January 1970.

Key Executive Personnel Changes

During the period, 16 changes affected NASA's key exeuctive personnel structure. These changes included five appointments, six reassignments, and five terminations.

Key Appointments.—On December 3, George M. Low was sworn in as Deputy Administrator of NASA. Dr. Low joined the staff of the NACA Lewis Flight Propulsion Laboratory in 1949. When NASA was organized, he was transferred to Washington (October 1958) where he served as the Chief of the Manned Space Flight Program. He was responsible for the Mercury and Gemini Programs and was Chairman of the special committee that formulated the original plans for the Apollo manned lunar landing. His last position in the Headquarters was as Deputy Associate Adminstrator for Manned Space Flight. From November 1, 1963, to April 10, 1967, he served as Deputy Director of the NASA Manned Spacecraft Center, Houston, Tex. From April 10, 1967, until his appointment as Deputy Administrator, he had served as Manager, Apollo Spacecraft Program Office at the Houston Center.

On September 12, Spencer M. Beresford was appointed as General Counsel of NASA. Mr. Beresford came from private law practice. During 1958 and 1959, he served as Special Counsel to the Select Committee on Astronautics and Space Exploration, and from 1959 to 1962 as Special Counsel to the Committee on Science and Astronautics, U.S. House of Representatives.

On October 1, 1969, Daniel J. Harnett was appointed as Assistant Administrator for Industry Affairs. Mr. Harnett came from the Northrop Corp., California, where he had been Director of Contracts, Pricing, and Programs.

On December 7, John M. DeNoyer was appointed as Director of Earth Observations Programs in the Office of Space Sciences and Applications. Dr. DeNoyer came from the U.S. Geological Survey where he had been Assistant Director for Research.

On December 18, 1969, John Adair Whitney was appointed as Assistant General Counsel for Procurement Matters. He came to NASA from private law practice, as a partner in the firm of Pope, Ballard, & Loos (Washington, D.C.).

Reassignments.—William R. Lucas was appointed as Director of Program Development, George C. Marshall Space Flight Center, on July 13. Previously, he had been Director, Propulsion and Vehicle Engineering Laboratory at the Center.

On September 1, Rocco A. Petrone was appointed to the position of Director, Apollo Program, within the Office of Manned Space Flight (Headquarters). Mr. Petrone had been Director of Launch Operations at the John F. Kennedy Space Center. He had served in numerous management capacities at the Center from August 1960

(Colonel, U.S. Army, detailed to NASA/Kennedy until his retirement from the Army, June 30, 1966).

Bruce T. Lundin was appointed Director, NASA Lewis Research Center (November 1). He joined NACA in 1943 as a research scientist at the Lewis Center, serving as Chief, Engine Research Division; Assistant Center Director; and Associate (Center) Director for Development. On August 1, 1968, he became Deputy Associate Administrator for Advanced Research and Technology (Headquarters); and from March 13, 1969, he served as Acting Associate Administrator for Advanced Research and Technology. (He continues to serve in this capacity in addition to the assignment at Lewis.)

On November 2, Lt. Gen. Frank A. Bogart, USAF, Retired, was appointed as Associate Director, NASA Manned Spacecraft Center, Houston, Tex. From September 1, 1965, to this date, General Bogart had been Deputy Associate Administrator for Manned Space Flight (Management), NASA Headquarters.

Christopher C. Kraft, Jr., was appointed as Deputy Director, NASA Manned Spacecraft Center on December 8. He had served as Director of the Flight Operations Program for the Mercury, Gemini, and Apollo Programs since December 22, 1963.

On December 28, Philip E. Culbertson was appointed as Director, Advanced Manned Missions Program. Prior to that time, he had been Director of Project Integration within the Apollo Applications Program Office, Office of Manned Space Flight. Mr. Culbertson joined the staff of the Office of Manned Space Flight in September 1965, coming from the General Dynamics/Convair Corp.

Terminations.—George H. Hage resigned from the position of Deputy Director, Apollo Program, Office of Manned Space Flight, on August 22. He had served in this capacity since October 1967. Previously he had been Deputy Associate Administrator for Space Science and Applications (Engineering).

On September 30, George S. Trimble, Jr., resigned from the position of Deputy Director, NASA Manned Spacecraft Center, Houston, Tex., having served in that capacity since November 1967. Previously, he had been Director, Advanced Manned Missions Program, Office of Manned Space Flight, Headquarters.

Dr. Abe Silverstein retired as Director, NASA Lewis Research Center, Cleveland, Ohio. He had served in this capacity since November 1, 1961. Earlier, he had been Director of Space Flight Development, NASA Headquarters, in the planning and develop-

ment of space science, manned, and unmanned space flight programs. Dr. Silverstein's 30-year career included assignments with both NACA and NASA. At Langley, he served as Chief, Full-Scale Wind Tunnel, from 1940 to 1943 and was then transferred to the new Lewis Research Laboratory to participate in its development. He was a division chief at Lewis until 1949, when he was made Chief of Research. Later (1952–58), he became Associate (deputy) Director of the Center.

On November 15, Paul G. Dembling resigned from the position of Deputy Associate Administrator to which he had been appointed in September 1969. Mr. Dembling had been with NACA and NASA since 1945. He was General Counsel of the NACA from 1954 until NASA was established. In NASA he was Assistant General Counsel; Director, Office of Legislative Affairs; Executive Director, Policy Planning Board; Deputy General Counsel; and General Counsel (January 1, 1967 to September 1969).

Dr. George E. Mueller resigned from the position of Associate Administrator for Mannel Space Flight (December 10). On September 1, 1963, Dr. Mueller came to NASA from the Space Technology Laboratories, Los Angeles. In NASA during the past 6 years, he headed the manned space flight programs and the basic "post-Apollo" planning activities.

NASA Awards and Honors

During this reporting period, the national goal of landing men on the moon and returning them safely to earth was accomplished. Special arrangements were made to recognize the significant individual contributions which made this achievement possible. The Administrator conducted a special awards ceremony at each of the manned space flight centers and one at Headquarters, Washington, D.C., to recognize the Government-Industry and University teams and their efforts in advancing the Nation's capabilities to aeronautics and space. The following awards are presented: NASA Distinguished Service Medal (35) ; NASA Distinguished Public Service Medal (2); NASA Exceptional Service Medal (297); NASA Exceptional Scientific Achievement Medal (31); Exceptional Bravery Medal (2) ; Group Achievement Award (17) ; and the Public Service Award (103).

Status of Personnel Force

These figures represent total employment (including temporaries) for the periods ending June 30, 1969, and December 31, 1969.

	June 1969	*December 1969*
Headquarters	2,293	2,160
Ames Research Center	2,117	1,986
Lewis Research Center	4,399	4,236
Langley Research Center	4,087	3,962
Flight Research Center	601	557
Electronics Research Center	951	872
Space Nuclear Propulsion Office	104	103
Goddard Space Flight Center	4,295	4,288
Wallops Station	554	513
NASA Pasadena Office	80	72
Marshall Space Flight Center	6,639	6,377
Manned Spacecraft Center	4,751	4,544
Kennedy Space Center	3,058	2,955
Total	33,929	32,625

INVENTIONS and CONTRIBUTIONS BOARD

On December 18, 1969, the Administrator of NASA redesignated the members of the Inventions and Contributions Board. Dr. Paul S. Johnson, Mr. Ronald J. Philips, and Mr. Clotaire Wood were designated as replacements for former members Mr. Melvin S. Day, Mr. Arthur D. Holzman, and Mr. Clarence R. Morrison. A listing of the present membership of the Board appears in appendix I.

Functions of the Board

NASA's Inventions and Contributions Board has three principal functions. First, it reviews petitions for waiver of patent rights submitted by NASA contractors, recommends disposition of each petition, and forwards its recommendations to the Administrator of NASA for final decision. Second, it considers and evaluates the merits of inventions and other scientific and technical contributions reported by NASA employees and NASA contractor employees. When the results are favorable, the Board is authorized to recommend that monetary awards be granted for qualified inventions and contributions, and to suggest an equitable amount for the award. The Board is also authorized to grant monetary awards of up to $5,000 (Government Employees' Incentive Awards Act of 1954) for inventions made by employees of the U.S. Government. Third, the Board also considers applications for award for scientific and technical contributions received from members of the general public, both foreign and domestic.

Board Actions on Petitions for Patent Waiver

The staff of the Board analyzed, evaluated, and presented to the Board 30 petitions for waiver of patent rights to individual inventions, as authorized by Section 305 of the Space Act. The Board's findings and recommendations were sent to the Administrator, who granted 28 petitions and denied two (petitioners and decisions are listed in appendix J). Six petitions for blanket waiver (the waiver of patent rights to all inventions which might be made during contract performance) were also considered by the Board. Of these, the Administrator granted four and denied two (petitioners and decisions are listed in appendix K).

In addition, the Administrator granted 16 petitions for patent waiver which had been considered and recommended for grant by the Advance Waiver Review Panel of the Board before the contracts were placed. (Petitioners and decisions are listed in app. K). This panel also considered three other petitions for waiver and recommended that they not be granted (app. K). In total, the Board and the Administrator acted on 55 petitions for waiver.

Summary on Commercialization of Waived Inventions

During the period, the staff of the Board distributed the second edition of "A Summary of Reports on Commercialization Activities of Patent Waiver Grantees" together with an explanatory analysis of the results. The second summary disclosed the fact that of all inventions to which the Agency waived patent rights before 1968, 59 had been fully commercialized. The staff also completed the preliminary work necessary for the preparation and distribution of the third edition of the summary. Inquiries were transmitted to contractor organizations for each of 401 inventions for which patent rights were waived by NASA before 1969. Responses to the requests were being analyzed and compilation of the third summary was underway at the close of this reporting period.

Publication of Patent Waiver Recommendations

NASA compiled a new supplement to the publication "PETITIONS FOR PATENT WAIVERS—Findings of Fact and Recommendation of NASA's Inventions and Contributions Board." The supplement is to be published, distributed to selected recipients, and made available for sale by the Superintendent of Documents early in 1970.

Monetary Awards for Inventions and Contributions

The Board recommended and the Administrator granted awards

in four categories. Forty-five monetary awards of $250 or more were recommended by the Board and granted by the Administrator of NASA to 67 employees of NASA and NASA contractor organizations. These awards were granted for inventions and other scientific and technical contributions which were judged to be of significant value in the conduct of an aeronautical or space program. (App. L.)

A total of 39 monetary awards of less than $250 were made to 50 employees of NASA following technical evaluation of reported inventions and other scientific and technical contributions.

Eighty-three minimum awards were granted for developing and reporting inventions upon which U.S. patent applications were subsequently filed. As a result, an award of $50 was made to each of 137 employees of NASA and NASA contractor organizations who were named in the patent applications.

A total of 159 *Tech Brief* awards were made; for these, payments of $25 minimum awards were made to 257 employees of NASA and NASA contractors who participated in the development and reporting of new technology and innovations which were subsequently published as NASA *Tech Briefs.*

A tabulation listing the number of awards granted, the number of recipients of awards, and the total amount of awards for each of the four categories described above appears on appendix L.

Incentive Act Awards

No awards were granted by the Board under the authority of the Government Employees Incentive Awards Act of 1954 during this period.

Other Activities

The Board revised its Award Evaluation Questionnaire (AEQ), the document which must be completed by a technical evaluator at Headquarters or, more frequently, at a NASA field installation for each monetary award case. It is the principal source of information which the Board uses to determine the technical merit of a contribution, and to estimate the amount of an equitable award. The new form was printed and supplies sent to field installations.

The Chairman of the Board and members of the staff continued their efforts to publicize the eligiblity of theoretical and other nonhardware contributions for consideration for an award. Response

from the NASA field installations indicates that there should be a sizeable increase in the number of applications for this type of award during the next year.

The Board did not hold any oral hearings during this period.

FINANCIAL MANAGEMENT

In June, the Comptroller General of the United States approved NASA's basic accounting system. Subsequently, the Agency concentrated its efforts on improving the quality of performance of its financial management functions. One notable accomplishment of this effort was the conclusion of the first operational review of the Agency's Contractor Financial Management Reporting System (NASA Form 533 series of reports). Installation project managers and their technical representatives, principal system users, were the focal point for the review. The review identified a number of system strengths in the form of beneficial and practical uses made of the information. These were publicized agency wide for consideration of their applicability at other installations. The review also highlighted several worthwhile revisions which would improve the effectiveness of the system. These will be included in an updating of the basic procedures handbook scheduled for calendar year 1970.

Fiscal Year 1971 Program

Table 10–1 shows the planned level of effort in research and development, construction of facilities, and research and program management for fiscal year 1971.

Table 10–1—NASA Budget Estimates Fiscal Year 1971
(In thousands)

Research and development:	
Apollo	$956,500
Space flight operations	515,200
Advanced missions	2,500
Physics and astronomy	116,000
Lunar and planetary exploration	144,900
Bioscience	12,900
Space applications	167,000
Launch vehicle procurement	124,900
Space vehicle systems	30,000
Electronics systems	22,400
Human factor systems	17,900
Basic research	17,600
Space power and electric propulsion systems	30,900
Nuclear rockets	38,000
Chemical propulsion	20,300
Aeronautical vehicles	87,100
Tracking and data acquisition	298,000
Technology utilization	4,000
Total, research and development	2,606,100
Construction of facilities	34,600
Research and program management	692,300
Total	3,333,000

Financial Reports, December 31, 1969

Table 10–2 shows fund obligations and accrued costs incurred during the 6 months ended December 31, 1969. Appended to the table is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1969.

Table 10–2—Status of Appropriations as of December 31, 1969

(In thousands)

Appropriations	*Six months ended December 31, 1969* *Obligations*	*Accrued costs*
Research and development:		
Apollo	$894,674	$774,806
Space flight operations	89,336	131,980
Advanced missions	881	3,049
Physics and astronomy	66,204	56,488
Lunar and planetary exploration	77,335	61,032
Bioscience	10,573	11,727
Space applications	35,525	41,870
Launch vehicle procurement	55,698	50,007
Sustaining university program	2,735	13,262
Space vehicle systems	9,260	12,639
Electronics systems	14,139	14,932
Human factor systems	8,784	10,643
Basic research	8,990	9,267
Space power and electric propulsion systems	21,806	21,472
Nuclear rockets	13,222	18,662
Chemical propulsion	10,145	14,746
Aeronautical vehicles	41,856	32,839
Tracking and data acquisition	142,846	128,007
Technology utilization	1,550	1,892
Reimbursable	30,730	31,017
Total, research and development	1,536,289	1,440,337
Construction of facilities	10,782	21,116
Research and program management	350,228	349,882
Total	1,897,299	1,811,335

Appropriation summary	*Current availability* [1]	*Total obligations*	*Unobligated balance*
Research and development	$3,370,439	$1,536,289	$1,834,150
Construction of facilities	100,639	10,782	89,857
Research and program management	647,476	350,228	297,248
	4,118,554	1,897,299	2,221,255

[1] *The availability includes authority for anticipated reimbursable orders.*

Table 10–3 shows NASA's consolidated balance sheet as of December 31, 1969, as compared to that of June 30, 1969. Table 10–4 summarizes the sources and applications of NASA's resources during the 6 months ended December 31, 1969. Table 10–5 provides an analysis of the net change in working capital disclosed in table 10–4.

Table 10–3.—NASA Comparative Consolidated Balance Sheet December 31, 1969, and June 30, 1969

(In millions)

Assets

	December 31, 1969	*June 30, 1969*
Cash:		
Funds with U.S. Treasury	$3,599.7	$1,738.9
Accounts receivable:		
Federal agencies	32.0	23.5
Other	13.1	13.2
	45.1	36.7
Inventories:		
NASA-held	49.3	40.5
Contractor-held	316.3	288.5
	365.6	329.0
Advances and prepayments:		
Federal agencies	10.2	14.2
Other	36.6	18.8
	46.8	33.0
Deferred charges	1.9	.3
Fixed assets:		
NASA-held	3,501.3	3,456.0
Contractor-held	873.6	822.2
Construction in progress	185.1	206.9
	4,560.0	4,485.1
Other assets:	731.9	322.8
Total assets	9,351.0	6,945.8

Liabilities and Equity

	December 31, 1969	*June 30, 1969*
Liabilities:		
Accounts payable:		
Federal agencies	116.9	121.5
Other	527.7	553.9
	644.6	675.4
Accrued annual leave	39.3	39.3
Deferred credits	-------	20.1
Total liabilities	683.9	734.8
Equity:		
Net investment	5,030.8	4,453.4
Undisbursed allotments	2,522.2	1,710.0
Unapportioned and unallotted appropriation	1,288.5	150.0
	8,841.5	6,313.4
Less reimbursable disbursing authority uncollected	174.4	102.4
Total equity	8,667.1	6,211.0
Total liabilities and equity	9,351.0	6,945.8

Table 10–4.—Resources Provided and Applied Six Months Ended December 31, 1969

(In millions)

Resources provided

Appropriations:	
Research and development	$3,006.0
Construction of facilities	53.2
Research and program management	636.9
Total appropriations	3,696.1
Revenues	27.4
Property transfers and retirements—net	18.5
Total resources provided	$3,742.0

Resources applied	*Total costs 6 months ended December 31, 1969*	*Less costs applied to assets*	
Operating costs:			
Research and development	$1,440.3	$502.5	$937.8
Construction of facilities	21.1	21.1	----------
Research and program management	349.9	1.8	348.1
Total	$1,811.3	$525.4	
Total operating costs			1,285.9
Increase in fixed assets:			
NASA-held			45.3
Contractor-held			51.4
Construction in progress			(21.8)
Total increase in fixed assets			74.9
Increase in working capital (table 10–5)			2,381.2
Total resources applied			$3.742.0

Table 10–5.—Net Change in Working Capital Six Months Ended December 31, 1969

(In millions)

	December 31, 1969	*June 30, 1969*	*Increase or (decrease)*
Current assets:			
Funds with U.S. Treasury	$3,599.7	$1,738.9	$1,860.8
Accounts receivable	45.1	36.7	8.4
Inventories	365.6	329.0	36.6
Advances and prepayments	46.8	33.0	13.8
Deferred charges	1.9	.3	1.6
Other assets	731.9	322.8	409.1
Total current assets	4,791.0	2,460.7	2,330.3
Current liabilities:			
Accounts payable	644.6	675.4	(30.8)
Deferred credits	---------	20.1	(20.1)
Total current liabilities	644.6	695.5	(50.9)
Working capital	4,146.4	1,765.2	
Increase in working capital			2,381.2

BOARD OF CONTRACT APPEALS

The NASA Board of Contract Appeals is the authorized representative of the Administrator to adjudicate the appeals of the Agency's contractors that arise under the "Disputes" clause of NASA contracts. The Board is comprised of five members appointed by the Administrator (listed in app. G). Its authority is established under procedures published in Title 14, Code of Federal Regulations, Part 1241 (*21st Semiannual Report*, p. 187).

During the period of this report, 16 new appeals were filed with the Board. The Board disposed of 24 appeals, including three motions for reconsideration. On December 31, 1969, the Board had 30 appeals pending on its docket.

CONTRACT ADJUSTMENT BOARD

The NASA Contract Adjustment Board considers requests by NASA contractors for equitable contractual relief under Public Law 85–804, when no administrative legal remedy is available. The Board's procedures are published in Title 41, Code of Federal Regulations, part 18–17. (Members of the Board are listed in app. F.)

The Board acted on three requests by contractors in this period. In one case, the relief requested was granted in part; the Board reconsidered its earlier decision denying relief on the same request, and recommended that the Contracting Officer review the contractor's entitlement to relief under changed criteria now in effect. In the two other cases the Board denied requests for relief.

The Board submits an annual report to Congress of all actions taken under the authority of Public law 85–804 during the preceding calendar year.

COST REDUCTION PROGRAM

NASA's Internal Cost Reduction Program yielded savings of $58,769,490, and its Contractor Cost Reduction Program reduced costs by approximately $80 million during the second half of 1969. NASA established an internal cost reduction goal of $120 million for Fiscal Year 1970. The Agency expects to meet the $120 million goal and hopes to exceed that amount in validated savings.

The Agency's Cost Reduction Program includes two major efforts. The Internal Cost Reduction Program encompasses ten field

installations and all of the principal Headquarters program and staff offices. The NASA Contractor Cost Reduction Program includes 32 of the Agency's major contractors who voluntarily participate in the formal reporting program. There is no overlapping or duplication between the two programs, although the concepts, standards, and criteria are quite similar.

Detailed cost reduction policies and procedures and a handbook have been published to provide guidance to NASA personnel on the operation of the program. In addition, an idea interchange system has been set up to publicize cost reduction techniques used by NASA and its contractors.

The Associate Deputy Administrator is responsible for implementing the program. It is managed by a Cost Reduction Board through a small permanent staff. The Board consists of the Associate Deputy Administrator (Chairman), the Associate Administrator for Organization and Management, the Assistant Administrator for Industry Affairs, and the Deputy Associate Administrator (Management) of the Office of Manned Space Flight. Cost Reduction Officers and Representatives have been designated in all Headquarters and field activities and assigned specific responsibilities in connection with both the Internal and the Contractor Cost Reduction Programs.

The staff of the Cost Reduction Office continued to evaluate the management and operation of both field installation and contractor cost reduction programs. The staff also conducted intensive reviews of quarterly cost reduction reports from more than 20 internal reporting activities and of semiannual reports from the 32 major NASA contractors. The Agency then used feedback reports and staff meetings to critique management at the reporting levels on the results of these reviews.

PROCUREMENT AND CONTRACT MANAGEMENT

Through its procurement and contract management activities, NASA continued to place stress on cost control, on careful scrutiny of contractor efforts, on sensible disperal of contracts to all States, and on making certain that small businesses received their fair share of NASA business.

Cost Sharing For Unsolicited Proposals

NASA's Appropriation Act for Fiscal Year 1970 requires contractors and grantees to share the cost of research work which re-

sults from unsolicited proposals. Because cost sharing requirements under prior legislation have been limited to research grants, revised operating instructions were needed to guide the field in applying the new cost sharing criteria. Accordingly, NASA issued interim instructions to all field centers for guidance and to industry groups and other affected private organizations for their information.

These interim instructions, informally cleared with the BOB and the GAO, identify the types of NASA activities affected by the cost sharing requirements and the types excluded from them. Additionally, field procurement personnel were directed to apply the new cost sharing criteria immediately to all appropriate procurement actions, including those then in process. Copies of the guidelines were made available to affected industry groups and other organizations for their information.

NASA Administrative Adoption of Public Law 91–121

NASA policy has been to recognize the cost of independent research and development (IR&D), bid and proposal (B&P), and other technical effort (OTE) as necessary business expenses, allowable to the extent that such costs are reasonable and allocable. This also is the policy of the Department of Defense. Under a new set of directions (Public Law 91–121), the Department of Defense may now reimburse IR&D, B&P and OTE at a level no greater than 93 percent of that amount it otherwise would have recognized as being reasonable. For consistency, NASA has chosen to observe the same limitation, even though not required to do so by law.

NASA Position on DoD Procurement Circular 74

Revisions and refinements continued to be made in the implementation of Public Law 87–653. DoD issued a procurement circular (No. 74), establishing the requirement for the contractor to furnish cost or pricing data for prospective subcontractors and to accept responsibility for its being current, complete, and accurate. This requirement became effective on January 1, 1970. At period's end, NASA was considering what action to take in regard to this policy, whether to follow the lead of DoD or set up its own requirements.

Incentive Contracting

NASA's contracting policies are designed to provide the flexibility needed to choose the most appropriate type of contract for the particular program or project. The choice depends on the degree of performance and cost responsibility assumed by the contractor,

and the amount and type of incentives determined necessary. NASA's experiences with incentives, generally, have been quite favorable. Lessons learned have resulted in improved selection criteria and structuring techniques. NASA continues to use the award fee contract and has worked closely with the Department of Defense on this and other matters relating to incentive contracting.

In October, 1969, the *DoD and NASA Incentive Contracting Guide* was issued. This guide resulted from a joint effort to provide previous incentive contracting experiences to buying organizations throughout both agencies. The guide is intended to set forth, under one reference, various aspects of incentive contracting that can be used by contracting officers to improve their methods of incentive contracting.

Provision of Government Facilities to Contractors

Other changes in the Procurement Regulation were made to improve the management of Government owned industrial property, and to further limit the circumstances under which Government facilities will be provided to contractors. Improved property administration procedures were instituted, contractor justification for obtaining Government facilities must now be signed at the corporate or company executive level, and the minimum limit for the furnishing of Government property was raised from $500 to $1000. These changes further NASA policy which states that contractors should normally furnish the facilities for the performance of Government contracts.

Contract Termination Procedures

NASA extensively revised its Procurement Regulation to establish more uniform policies and procedures with regard to contract terminations. The revision provides for the appointment of Termination Contracting Officers (TCO) to be responsible for the procedural, administrative, and management control of contract termination matters. Termination settlement procedures were strengthened to facilitate the settlement process and to ensure appropriate NASA management review and approval of proposed settlement agreements or determinations.

Conduct of Written or Oral Discussions

A review of the procedures used in NASA source selections indicated a lack of uniformity in applying the requirement of 10 USC 2304(g) that written or oral discussions be held with all

concerns whose proposals are within a competitive range. Accordingly, a Procurement Regulation Directive (PRD) was issued to provide NASA procurement personnel and Source Selection Boards with additional uniform guidance.

As the statutory requirement regarding the conduct of written or oral discussions is relatively recent, the implementing rules governing its application to Federal agencies generally are still evolving. Accordingly, while the PRD reflects current NASA thinking, further revision may be dictated by future events.

Minority Business Enterprise

NASA continued to take any active part in Federal efforts to assist minority business enterprises by encouraging their participation in Government procurement programs. Field centers were alerted to identify work which could be accomplished by minority firms. Special surveys were conducted by all centers during the past year to locate minority firms and place them on bidders' lists. Several meetings and seminars were co-sponsored by NASA with other Government agencies and educational institutions to acquaint minority businessmen with contracting opportunities available to them. In addition, NASA has a very active part in the work of the interagency Task Force on Federal Procurement. This group, established earlier this year at the request of the Executive Office of the President to promote minority business enterprise, brings together the Commerce Department's Office of Minority Business Enterprise, the SBA, and the major Government procurement agencies.

Summary of Contract Awards

NASA's procurements for the first 6 months of Fiscal Year 1970 (this report period) totalled $1,627 million. This is $352 million less than was awarded during the corresponding period of Fiscal Year 1969.

Approximately 81 percent of the net dollar value was placed directly with business firms, 5 percent with educational and other non-profit institutions, 6 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 7 percent with or through other Government agencies, and 1 percent outside the United States.

Contracts Awarded to Private Industry

Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies on behalf of

NASA. In addition, about 62 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 91 percent of NASA's procurement dollars was contracted to private industry.

Fifty-nine percent of the total direct awards to business firms represented competitive procurements, either through formal advertising or competitive negotiation. Forty-one percent constituted noncompetitive procurements. With respect to the competitive procurements, 7 percent of the total awards represented new contracts and 52 percent constituted within scope modifications (incremental funding actions and change orders) to contracts awarded competitively in prior years. Of the noncompetitive procurements, 6 percent of the total awards represented new contracts and 35 percent constituted noncompetitive modifications to contracts awarded previously. Of these noncompetitive procurements, 17 percent of the total awards represented follow-on after competition awards to companies that had been previously selected on a competitive basis to perform the original research and development on the applicable projects. In these instances, selection of another source would have required an extensive period of preparation for manufacturing and additional cost to the Government by reason of duplication of investment and preparation. The remaining 24 percent of noncompetitive procurements included awards arising from acceptable unsolicited proposals offering new ideas and concepts; awards to contractors having unique capabilities to meet particular requirements of the Government; and awards for sole source items.

Small business firms received $65 million, or 5 percent of NASA's direct awards to business firms. However, most of the awards to business firms were for large continuing research and development contracts for major systems and major items of hardware. These are generally beyond the capability of small business firms on a prime contract basis. Of the $176 million of new contracts of $25,000 and over awarded to business firms during the 6 months, small business received $23 million, or 13 percent.

In addition to the direct awards, small business received substantial subcontract awards from 78 of NASA's prime contractors participating in its Small Business Subcontracting Program. Total direct awards plus known subcontract awards aggregated $123 million, or 9 percent of NASA's total awards to business during the first half of Fiscal Year 1970.

Geographical Distribution of Prime Contracts

Within the United States, NASA's prime contract awards were distributed among 45 States and the District of Columbia. Business firms in 41 States and the District of Columbia, and educational institutions and other nonprofit institutions in 42 States and the District of Columbia, participated in the awards. One percent of the awards went to labor surplus areas located in 10 States.

Subcontracting

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 20 States and the District of Columbia reported that their larger subcontract awards on NASA effort had gone to 668 subcontractors in 37 States and the District of Columbia, and that 65 percent of these subcontract dollars had crossed State lines.

Major Contract Awards

Among the major research and development contract awards by NASA during the first six months of Fiscal Year 1970 were the following:

1. North American Rockwell Corp., Downey, Calif. NAS9–150. Design, develop, and test Apollo command and service module. Awarded $164 million; cumulative awards $3,623 million.

2. Grumman Aerospace Corp., Bethpage, N.Y. NAS9–1100. Development of Apollo lunar module. Awarded $161 million; cumulative awards $2,075 million.

3. North American Rockwell Corp., Downey, Calif. NAS7–200. Design, develop, fabricate, and test the S–II stage of the Saturn V vehicle and provide launch support services. Awarded $75 million; cumulative awards $1,344 million.

4. The Boeing Co., New Orleans, La. NAS8–5608. Design, develop and fabricate the S–IC stage of the Saturn V vehicle, construct facilities in support of the S–IC stage and provide launch support services. Awarded $74 million; cumulative awards $1,452 million.

5. McDonnell Douglas Corp., Santa Monica, Calif. NAS7–101. Design, develop and fabricate the S–IVB stage of the Saturn V vehicle and associated ground support equipment and provide launch support services. Awarded $42 million; cumulative awards $1,099 million.

6. McDonnell Douglas Corp., St. Louis, Mo. NAS9–6555. Design, develop, and fabricate orbital workshops (modified Saturn S–IVB

stages) and airlock modules for Skylab Program and provide operational support. Awarded $39 million; cumulative awards $118 million.

7. General Electric Co., Huntsville, Ala. NASW–410. Apollo checkout equipment, related engineering design, quality and data management and engineering support; support services to Mississippi Test Facility. Awarded $34 million; cumulative awards $788 million.

8. North American Rockwell Corp., Canoga Park, Calif. NAS8–19. Develop and procure 200,000-pound thrust J–2 rocket engine with supporting services and hardware. Awarded $23 million; cumulative awards $677 million.

9. International Business Machines Corp., Huntsville, Ala. NAS8–14000. Fabrication, assembly, and checkout of instrument units for Saturn I and V vehicles. Awarded $22 million; cumulative awards $348 million.

10. Trans World Airlines, Inc., Kennedy Space Center, Fla. NAS10–1242. Provide base support services at Kennedy Space Center. Awarded $22 million; cumulative awards $139 million.

11. Bendix Corp., Kennedy Space Center, Fla. NAS10–1600. Apollo launch support services at Kennedy Space Center. Awarded $21 million; cumulative awards $134 million.

12. Bendix Corp., Owings Mills, Md. NAS5–10750. Maintenance and operation of the Manned Space Flight Network. Awarded $19 million; cumulative awards $78 million.

13. Grumman Aerospace Corp., Bethpage, N.Y. NAS5–814. Design and develop S–18, S–58 Orbiting Astronomical Observatories. Awarded $15 million; cumulative awards $199 million.

14. TRW, Inc., Houston, Tex. NAS9–8166. Apollo spacecraft systems analyses program. Awarded $15 million; cumulative awards $50 million.

15. Aerojet-General Corp., Sacramento, Calif. SNP–1. Design, develop and produce a nuclear powered rocket engine (NERVA). Awarded $13 million; cumulative awards $516 million.

16. Philco-Ford Corp., Palo Alto, Calif. NAS9–1261. Equipment and construction of facilities for the Integrated Mission Control Center. Awarded $12 million; cumulative awards $152 million.

17. International Business Machines Corp., Houston, Tex. NAS9–996. Design, develop, and implement real time computer complex for Integrated Mission Control Center at the Manned

Spacecraft Center. Awarded $12 million; cumulative awards $149 million.

18. Martin Marietta Corp., Denver, Colo. NAS1–9000. Viking lander system and project integration. Awarded $12 million (new contract).

19. McDonnell Douglas Corp., Santa Monica, Calif. NAS7–764. Procurement, preparation for launch and launch of Delta space research vehicle. Awarded $11 million (new contract).

20. Federal Electric Corp., Kennedy Space Center, Fla. NAS10–4967. Provide communications, instrumentation and computer operation support services for KSC facilities. Awarded $11 million; cumulative awards $47 million.

Major Contractors

The 25 contractors receiving the largest direct awards (net value) during the first 6 months of Fiscal Year 1970 were as follows:

	Contractor and Place of Contract Performance	*Thousands*
1.	North American Rockwell Corp., Downey, Calif. *	$277,329
2.	Grumman Aerospace Corp., Bethpage, N.Y. *	175,545
3.	McDonnell Douglas Corp., Santa Monica, Calif. *	108,791
4.	Boeing Co., New Orleans, La. *	97,381
5.	General Electric Co. Huntsville, Ala. *	64,520
6.	Bendix Corp., Owings Mills, Md. *	64,329
7.	International Business Machines Corp., Huntsville, Ala. *	55,563
8.	Martin Marietta Corp., Denver, Colo. *	25,424
9.	Trans World Airlines, Inc., Kennedy Space Center, Fla	22,783
10.	Aerojet-General Corp., Sacramento, Calif. *	19,663
11.	RCA Corp., Camden, N.J. *	18,384
12.	Lockheed Aircraft Corp., Houston, Tex. *	18,279
13.	TRW, Inc., Houston, Tex. *	17,868
14.	Sperry Rand Corp., Greenbelt, Md. *	17,009
15.	Philco-Ford Corp., Houston, Texas *	13,970
16.	Federal Electric Corp., Kennedy Space Center, Fla. *	12,869
17.	General Dynamics Corp., San Diego, Calif. *	12,012
18.	United Aircraft Corp., Windsor Locks, Conn. *	11,006
19.	General Motors Corp., Milwaukee, Wisc. *	10,651
20.	Service Technology Corp., Kennedy Space Center, Fla. *	9,739
21.	LTV Aerospace Corp., Dallas, Tex. *	9,446
22.	Brown/Northrop (Joint Venture), Houston, Tex	7,897
23.	ILC Industries, Inc., Dover, Del	7,543
24.	Chrysler Corp., New Orleans, La. *	6,952
25.	Ball Brothers Research Corp., Boulder, Colo	6,555

*Awards during year represent awards on several contracts which have different principal places of performance. The place shown is that which has the largest amount of awards.

LABOR RELATIONS

During the last 6 months of 1969, man-days lost as the result of strikes on construction contracts at all NASA Centers decreased approximately 50 percent to 1262 from 2421 during the first half of 1969. Work stoppages during the last half of 1969 were caused by a cross section of typical construction labor problems. Negotiations of labor contracts in Southern California construction crafts accounted for 1042 man-days lost. Remaining time lost was caused by jurisdicitional disputes and grievances.

Man-days lost on Center industrial contracts increased from 24 during the first 6 months of 1969 to 720 in the last half of 1969. Practically all the increase resulted from a single strike of the electricians at MSC brought on by a lengthy dispute over a grievance.

RELIABILITY AND QUALITY ASSURANCE

The reliability and quality assurance lessons learned in the ATLAS-CENTAUR ATS–D launch vehicle failure and actions taken to prevent reoccurrence were distributed NASA-wide. Similar followup action on the DELTA 59/INTELSAT F–1 failure was expanded with R&QA participation in the investigation of the DELTA 71/INTELSAT F–5 and DELTA 73 Pioneer failures. The R&QA aspects of THOR and THOR DELTA vehicle programs were studied through participation in the NASA (OSSA) Launch Vehicle Review Board. Action to improve implementation of requirements for quality assurance on the DELTA program was initiated.

Basic contractual quality assurance requirements for NASA aeronautical and space systems were updated and revised with issuance of NHB 5300.4(1B). Similarly, basic reliability program requirements and micro-electronics reliability requirements were undergoing final review for publication. Quality Assurance requirements in the NASA Procurement Regulation were being revised and undergoing final review so as to be consistent with current and improved procurement practices.

RELATIONSHIPS WITH OTHER GOVERNMENT AGENCIES

NASA's Office of DoD and Interagency Affairs continued to coordinate Agency wide assistance to, and support from, other Fed-

eral agencies engaged in or using the results of aerospace related research and development.

The Aeronautics and Astronautics Coordinating Board (AACB) is the principal coordinating mechanism between NASA and DoD and is composed of panels on aeronautics, launch vehicles, manned space flight supporting research and technology, space flight ground environment, and unmanned spacecraft. The AACB continued to serve as an initial link in the exchange of information, review and coordination of aeronautical and space programs, consideration of joint studies, and other activities.

The Aeronautics Panel continued its efforts to determine costs, schedules, and priorities associated with the acquisition of major new aerospace research facilities. A joint facilities working group was making initial designs and cost estimates of these facilities.

The AACB continued its review of the coordination process relating to the Space Transportation System (now in a study phase) which will support the needs of both NASA and DoD for a reuseable, earth to orbit shuttle system.

The AACB also conducted an examination of the status of fighter aircraft technology, as seen by members of the Lewis and Langley Research Centers. It reviewed the report of the Space Task Group, established by the President in February 1969, to provide a coordinated space program and budget for the post Apollo period. It coordinated the NASA/DoD Fiscal Year 1970 Facilities Programs. Additionally, it reviewed the results of twelve selected DoD-NASA economy studies.

Through AACB efforts, NASA concluded an agreement with the Army on November 12, augmenting the Army unit at Ames and establishing similar Army research activities at Langley and Lewis. By this action the Army will expand significantly its research program in low speed and rotary aviation. The personnel will remain as Army employees, but for the most part will be under technical direction of NASA laboratory supervisors. They will at the same time enhance the Army's research capability, and provide additional support to NASA projects of common interest with the Army. Plans call for some 175 new personnel to be employed by the end of Fiscal Year 1970.

In the area of communications satellites, NASA assisted the Department of Commerce and Alaska in identifying possible uses of communications satellites to meet that State's telecommunication requirements. NASA also assisted a White House working

group in developing guidelines for use by the Federal Communications Commission in connection with the U.S. domestic communications satellite programs. In addition, NASA consulted with such organizations as the Office of Education and the National Library of Medicine of the Department of Health, Education, and Welfare; the Division for the Blind and Physically Handicapped of the Library of Congress; and the Corporation for Public Broadcasting regarding the possible applications of communications satellite technology in meeting their specific requirements.

Collaboration between NASA and the military services continued, with military personnel being assigned to NASA for 2-to 3-year tours. Of particular interest were the assigning to NASA of some of the specialists freed by the cancellation of the DoD Manned Orbiting Laboratory program and notice by the Air Force that it intends to reduce its large contingent of assignees at the Manned Spacecraft Center.

NASA and DoD continued their joint study on ways and means of achieving economies in manpower and other resources in common endeavors. In particular, the two agencies considered the consolidation of specific support activities at the Kennedy Space Center and at the Air Force Eastern Test Range.

This office also coordinated NASA's report to the Space Task Group, which was appointed by the President in February 1969 to recommend space objectives and budget options for the post-Apollo period. The NASA report to the Task Group and the Task Group report to the President were both released to the public on September 17. Subsequently, they were widely distributed to individuals and agencies within and outside the Government.

In addition, this office handled the negotiation and consummation of agreements between NASA and other Federal agencies. Those processed and approved covered such activities as the loan of DoD operational and research aircraft to NASA, DoD support of NASA at Vandenberg Air Force Base, DoD support of NASA contract administration, DoD support of NASA tracking stations, NASA support of the National Search and Rescue Program, and NASA support of the General Services Administration's air pollution control program.

THE NASA SAFETY PROGRAM

Through its Safety Program, NASA continued its efforts to identify hazards, determine risks, and prevent accidents. To accom-

plish these objectives, the Agency is using the safety evaluation technique which includes reviews of both the NASA field installations and space hardware development and operation programs.

Safety evaluations were completed at 11 field installations. This effort included the review of eight of the aerospace programs. Reports of the evaluations, which contain corrective action recommendations, were sent to appropriate management offices. These evaluations, together with previous safety reviews, constitute a specific safety performance baseline, against which improvement may be measured during future evaluations.

System Safety

A small working group, comprised of representatives from industry who have achieved recognition as experts in the field of system safety, was assembled to develop a system safety technology handbook for NASA. This manual is a new concept in the field of safety, stressing both management techniques and technical methods. Its publication as Volume III of the NASA Safety Manual is anticipated early in 1970.

The Safety Analysis Report (SAR) concept was implemented in the Apollo Program, and was being incorporated into the other NASA projects. The SAR is a letter report published prior to each mission to document the mission risks and provide the rationale for their assumption.

System safety program evaluations were being scheduled for completion at a steady rate, with emphasis on follow-up and the corrective actions implemented as a result of the recommendations.

Industrial Safety

NASA has assigned additional safety specialists at Headquarters and field installations and initiated additional program activities as a result of the periodic evaluations of field installation safety programs. The Agency made its accident reporting and formal investigations more prompt and more detailed for use in accident prevention applications.

Internal safety communications were improved through dissemination of guidance material by the NASA Safety Office, a freer exchange of in-house experiences, and the broader use of the NASA *Safety Journal.* A NASA Safety Film Library was being developed. NASA Safety Office personnel participated in a record number of both in-house and non-NASA committee meetings, hearings,

safety councils, and professional conferences. They also made numerous presentations, carrying the NASA safety story to both Government and industry audiences.

Aviation Safety

Significant new steps were taken to improve the NASA Aviation Safety Program. A NASA Aviation and Standardization Committee (NASSC) was formed in September. Representation included personnel from Headquarters, the program offices, and various field installations who have broad aviation experience.

Aviation safety plans, requirements, and guidelines were developed during this meeting, and the committee was organized into eight working groups which include the following areas of interest: Operating standards, aviation safety surveys, aviation safety information, aviation facilities, aircraft safety equipment/survival training, aircraft accident/incident prevention and education, contracting requirements, and aviation maintenance and modifications.

These working groups began developing a NASA Aircraft Operating Manual to standardize the basic operating requirements and flight safety practices so there will be uniformity in all NASA aircraft maintenance and operations. Members of the working groups, together with a contracted team from the Flight Safety Foundation, conducted a survey of operating practices, procedures, and standards being followed at each NASA installation. This survey was completed before work started on the Operating Manual.

A meeting was held by the Aviation Maintenance and Modification Committee during December in conjunction with the FAA Aviation Maintenance Seminar at Oklahoma City. Other meetings were being held with the individual groups and the Acting Assistant Director of Safety (Aviation) so that guidance can be provided to the working groups.

Fire Prevention

NASA concentrated its emphasis on fire prevention education and training to improve the skills of the present field installation fire protection staffs.

The fire protection orientations were being planned for use with three organizational levels, managers, engineers, and fire service personnel. The orientations should develop a better understanding of risk assessment, hazard analysis, fire protection, and prevention

principles. Also, posters and fire prevention information were furnished throughout NASA, emphasizing fire prevention to NASA employees. These were circulated in response to the President's proclamation for the national observance of Fire Prevention Week.

The Federal Fire Council's *Recommended Practices for Fire Protection for Essential Electronic Equipment,* RP–1 (Revised July 1969), was adopted as the recommended practice for NASA. The use of this Standard will assure that the best available Federal experience is applied within NASA.

The NASA Facility Engineering Handbook (NPC 321–1) was updated during the period and reissued as NHB 7320.1. Safety and fire protection requirements were included during the revision. These requirements apply both to the modification and repair of buildings and facilities, and to the construction of new facilities.

General Activities and Accomplishments

The NASA Safety office sponsored its annual conference during November. Participants included safety personnel from all field installations. The purpose of the conference was to get the safety professionals together for an exchange of ideas, techniques, and experiences in safety.

The NASA Safety Manual, NHB 1700.1, Volume 1, *Basic Safety Requirements,* was published in July. This document sets forth the total NASA safety requirements for all field installations in the areas of system, industrial, public, and aviation safety.

The NASA Procurement Regulation was revised to include a mandatory safety clause for major NASA contracts. This clause assures that specific safety requirements are defined in all major procurements of both facilities and aerospace hardware systems.

A comparison of the NASA accident frequency rate through November with the goal established in the President's Mission SAFETY 70 Program reveals that NASA is well ahead of the goal. The NASA frequency rate is 0.97 against the goal rate of 1.9 per million manhours worked.

Manned Space Flight Efforts

NASA placed particular emphasis on the Manned Flight Awareness Program in order to minimize a possible post lunar landing letdown in morale and quality of workmanship. The Agency held a Manned Flight Awareness Seminar in September which included representation from industry. The theme of the seminar was "The

Future of Manned Space Flight." Senior NASA management officials briefed contractors on future Apollo Applications Programs, planned lunar exploration operations, the Space Station, the Space Shuttle, and Advanced Manned Missions so they could relieve worker apprehension concerning the future. Other actions to maintain morale included selecting approximately 400 workers as honorees to view the launch of Apollo 11 and 12 in recognition of their outstanding achievements in the Apollo Program; and establishing a visitation program by astronauts and senior Apollo program management personnel to NASA installations and contractor facilities to make appropriate awards to deserving workmen.

The 1969 safety survey schedule was completed with a survey at KSC and an informal survey of the MTF, MAF, Slidell Computer Complex, White Sands KSC–WTR, and the Seal Beach Facility. Fifteen recommendations were made concerning nuclear safety, unmanned launch operations, medical safety, and fire prevention. Several other discrepancies were corrected during the survey.

Accident/incident history was compiled to accumulate data on mishaps that have occurred in manned space flight activities and contractor plants. This listing is to be published in the near future and distributed to all NASA agencies with the aim of assisting in accident prevention for future MSF programs.

A safety review was made of the "Apollo 11 Crew Technical Debriefing," and safety-oriented anomalies were called to the attention of appropriate NASA agencies for use in planning and conducting future flights. A similar review was being made of the "Apollo 12 Crew Technical Debriefing."

Considerable progress was made in applying NASA expertise to other safety areas. For example, NASA safety representatives visited several coal mines in the Pittsburgh area to observe their rescue procedures and equipment and discuss safety problems associated with coal mining emergencies. Mine safety and rescue personnel were invited to visit KSC to exchange ideas and information. Also, assistance was being provided to the National Academy of Engineering in starting a 5- to 7-year R&D coal mining safety program.

The possible use of some of the nonmetallic fire prevention materials developed by NASA to enhance the fire safety of civilian and military aircraft was being studied. Flammability demonstrations of these materials were made to representatives of United Air Lines, the Air Line Pilots Association, and the National Fire Pro-

tection Association. As a result of the initial response to these presentations, a large public seminar was being planned for April, 1970.

A number of safety documents were developed or were in the process during the period. These included *System Safety Requirements for MSF, Safety Guidelines for Certification of Personnel Involved in Hazardous Operations, Safety Guidelines for Man-Rating Altitude Chambers, Safety Guidelines for Man-Rating Hyperbaric Chambers, Safety Guidelines for Designating Operations, Safety Guidelines for Overtime Work Limitations in Ground Operations, Safety Surveys, and Accident-Incident/Mission Failure Investigation and Reporting Guidelines.*

Appendix A

Congressional Committees on Aeronautics and Space

(July 1–December 31, 1969)

Senate Committee on Aeronautical and Space Sciences

CLINTON P. ANDERSON, New Mexico, *Chairman*
RICHARD B. RUSSELL, Georgia
WARREN G. MAGNUSON, Washington
STUART SYMINGTON, Missouri
JOHN STENNIS, Mississippi
STEPHEN M. YOUNG, Ohio
THOMAS J. DODD, Connecticut
HOWARD W. CANNON, Nevada
SPESSARD L. HOLLAND, Florida
MARGARET CHASE SMITH, Maine
CARL T. CURTIS, Nebraska
MARK O. HATFIELD, Oregon
BARRY M. GOLDWATER, Arizona
WILLIAM B. SAXBE, Ohio
RALPH T. SMITH, Illinois

House Committee on Science and Astronautics

GEORGE P. MILLER, California, *Chairman*
OLIN E. TEAGUE, Texas
JOSEPH E. KARTH, Minnesota
KEN HECHLER, West Virginia
EMILIO Q. DADDARIO, Connecticut
JOHN W. DAVIS, Georgia
THOMAS N. DOWNING, Virginia
JOE D. WAGGONNER, Jr., Louisiana
DON FUQUA, Florida
GEORGE E. BROWN, Jr., California
EARLE CABELL, Texas
BERTRAM L. PODELL, New York
WAYNE N. ASPINALL, Colorado
ROY A. TAYLOR, N.C.
HENRY HELSTOSKI, New Jersey
MARIO BIAGGI, New York
JAMES W. SYMINGTON, Missouri
EDWARD I. KOCH, New York
JAMES G. FULTON, Pennsylvania
CHARLES A. MOSHER, Ohio
RICHARD L. ROUDEBUSH, Indiana
ALPHANZO BELL, California
THOMAS M. PELLY, Washington
JOHN W. WYDLER, New York
GUY VANDER JAGT, Michigan
LARRY WINN, Jr., Kansas
JERRY L. PETTIS, California
DONALD E. LUKENS, Ohio
ROBERT PRICE, Texas
LOWELL P. WEICKER, Jr., Connecticut
LOUIS FREY, Jr., Florida
BARRY M. GOLDWATER, Jr., California

Senate Appropriations Committee
Subcommittee on Independent Offices

JOHN O. PASTORE, Rhode Island, *Chairman*
WARREN G. MAGNUSON, Washington
ALLEN J. ELLENDER, Louisiana
RICHARD B. RUSSELL, Georgia
SPESSARD L. HOLLAND, Florida
JOHN STENNIS, Mississippi
MICHAEL J. MANSFIELD, Montana
GORDON ALLOTT, Colorado
MARGARET CHASE SMITH, Maine
ROMAN L. HRUSKA, Nebraska
NORRIS COTTON, New Hampshire
CLIFFORD CASE, New Jersey

House Appropriations Committee
Subcommittee on Independent Offices

JOE L. EVINS, Tennessee, *Chairman*
EDWARD BOLAND, Massachusetts
GEORGE SHIPLEY, Illinois
ROBERT GIAMO, Connecticut
JOHN MARSH, Virginia
DAVID PRYOR, Arkansas
CHARLES JONAS, North Carolina
LOUIS WYMAN, New Hampshire
BURT TALCOTT, California
JOSEPH MCDADE, Pennsylvania

Ex Officio: Senator Milton R. Young, North Dakota

Ex Officio on Aeronautical and Space Activities: Senators CLINTON P. ANDERSON, New Mexico; STUART SYMINGTON, Missouri; CARL T. CURTIS, Nebraska.

Appendix B

National Aeronautics and Space Council

(July 1–December 31, 1969)

Spiro T. Agnew, *Chairman*
Vice President of the United States

William P. Rogers
Secretary of State

Melvin R. Laird
Secretary of Defense

Thomas O. Paine, *Administrator*
National Aeronautics and Space Administration

Glen T. Seaborg, *Chairman*
Atomic Energy Commission

Executive Secretary
William A. Anders

Appendix C

Principal NASA Officials at Washington Headquarters
(December 31, 1969)

DR. THOMAS O. PAINE	Administrator
DR. GEORGE M. LOW	Deputy Administrator
DR. HOMER E. NEWELL	Associate Administrator
WILLIS H. SHAPLEY	Associate Deputy Administrator
BERNARD MORITZ	Acting Associate Administrator for Organization and Management
WILLIAM E. LILLY	Assistant Administrator for Administration
DANIEL J. HARNETT	Assistant Administrator for Industry Affairs
BERNARD MORITZ	Assistant Administrator for Special Contracts Negotiation and Review
MELVIN S. DAY	Acting Assistant Administrator for Technology Utilization
FRANCIS B. SMITH	Assistant Administrator for University Affairs
DEMARQUIS D. WYATT	Assistant Administrator for Program Plan and Analysis
DR. ALFRED J. EGGERS, Jr	Assistant Administrator for Policy
JACOB E. SMART	Assistant Administrator for DOD and Interagency Affairs
CHARLES E. WEAKLEY	Assistant Administrator for Management Development
SPENCER G. BERESFORD	General Counsel
ARNOLD W. FRUTKIN	Assistant Administrator for International Affairs
ROBERT F. ALLNUTT	Assistant Administrator for Legislative Affairs
JULIAN SCHEER	Assistant Administrator for Public Affairs
DR. GEORGE E. MUELLER	Associate Administrator for Manned Space Flight
DR. JOHN E. NAUGLE	Associate Administrator for Space Science and Applications
GERALD M. TRUSZYNSKI	Associate Administrator for Tracking and Data Acquisition
BRUCE T. LUNDIN	Acting Associate Administrator for Advanced Research and Technology

(Telephone information: 963-7101)

Appendix D

Current Official Mailing Addresses for Field Installations.

nstallation and telephone number	Official	Address
Ames Research Center; 415–961–1111.	Dr. Hans M. Mark, Director	Moffett Field, Calif. 94035.
Electronic Research Center; 617–494–2000.	Mr. James C. Elms, Director	575 Technology Square, Cambridge, Mass. 02139.
Flight Research Center; 805–258–3311.	Mr. Paul Bikle, Director	Post Office Box 273, Edwards, Calif. 93523.
Goddard Space Flight Center; 301–982–5042	Dr. John F. Clark, Director	Greenbelt, Md. 20771.
Goddard Institute for Space Studies; 212–UN6–3600.	Dr. Robert Jastrow, Director	2880 Broadway, New York, N.Y. 10025.
Jet Propulsion Laboratory; 213–354–4321	Dr. W. H. Pickering, Director	4800 Oak Grove Dr., Pasadena, Calif. 91103.
John F. Kennedy Space Center; 305–867–7113.	Dr. Kurt H. Debus, Director	Kennedy Space Center, Fla. 32899.
Langley Research Center; 703–827–1110.	Mr. Edgar M. Cortright, Director.	Langley Station, Hampton, Va. 23365.
Lewis Research Center; 216–433–4000.	Mr. Bruce T. Lundin, Director	21000 Brookpark Rd., Cleveland, Ohio 44135.
Manned Spacecraft Center; 713–HU3–3111.	Dr. Robert R. Gilruth, Director.	Houston, Tex. 77058.
George C. Marshall Space Flight Center; 205–453–3131.	Dr. Wernher von Braun, Director.	Marshall Space Flight Center, Ala. 35812.
Michoud Assembly Facility; 504–255–3311.	Dr. George N. Constan, Manager.	Post Office Box 29300, New Orleans, La. 70129.
Mississippi Test Facility; 601–688–2211.	Mr. Jackson M. Balch, Manager.	Bay St. Louis, Miss. 39520.
KSC Western Test Range Operations Division; 805–866–1611.	Mr. H. R. Van Goey, Chief	Post Office Box 425, Lompac, Calif. 93436.
Plum Brook Station; 419–625–1123.	Mr. Alan D. Johnson, Director	Sandusky, Ohio 44871.
Wallops Station; 703–VA4–3411	Mr. Robert L. Krieger, Director.	Wallops Island, Va. 23337.

Appendix E

NASA Historical Advisory Committee

(December 31, 1969)

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JAMES LEA CATE, Department of History, University of Chicago
EARL DELONG, Dean, School of Government and Public Administration, The American University
A. HUNTER DUPREE, Department of History, Brown University
JOE B. FRANTZ, Department of History, University of Texas
LOUIS MORTON, Department of History, Dartmouth College
ROBERT L. PERRY, Economics Division, The RAND Corporation
Executive Secretary: EUGENE M. EMME, NASA Historian

Appendix F

NASA Contract Adjustment Board

(December 31, 1969)

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	FRANK J. SULLIVAN
	MELVYN SAVAGE
	WILLIAM E. STUCKMEYER

Appendix G

NASA Board of Contract Appeals

(December 31, 1969)

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	DONALD W. FRENZEN
	RICHARD R. PIERSON
Recorder	(MISS) ROSE M. SZWAST

Appendix H

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(December 31, 1969)

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THORNTON PAGE—Wesleyan University (NAS/MSC)
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HELLMUT SCHMID—Environmental Science Services Administration/Rockville, Md.
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FRIEDRICH O. VONBUN—Goddard Space Flight Center

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PHILIP D. THOMPSON—National Center for Atmospheric Research
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PAUL ROSENBERG—Paul Rosenberg Associates
GEORGE C. WEIFFENBACH—Johns Hopkins University
JAMES B. WOODFORD, Jr.—Aerospace Corp.

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WILLIAM W. KELLOGG—National Center for Atmospheric Research

ALFRED O. C. NIER—University of Minnesota
ILIA POPPOFF—Ames Research Center
ANDREW E. POTTER—Manned Spacecraft Center
NELSON W. SPENCER—Goddard Space Flight Center

Consultants:
CHARLES BARTH—University of Colorado
DARRELL L. JUDGE—University of Southern California
LESTER LEES—California Institute of Technology
FREDERICK F. MARMO [1]—GCA Corp.
THOMAS K. MCCUBBIN—Pennsylvania State University
GUIDO MUNCH—California Institute of Technology

Planetary Biology

Chairman:
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WILLIAM A. BAUM—Lowell Observatory
BEVAN M. FRENCH—Goddard Space Flight Center
PAUL GAST—Lamont-Doherty Geological Observatory of Columbia University

[1] **Change made by this revision.**

CLARK D. GOODMAN—University of Houston
ROBERT J. MACKIN—Jet Propulsion Laboratory
BRIAN H. MASON—Smithsonian Institution
THOMAS A. MUTCH—Brown University
HARRISON H. SCHMITT—Manned Spacecraft Center
ANTHONY L. TURKEVICH—University of Chicago
DON E. WILHELMS—U.S. Geological Survey/Menlo Park, Calif.
DONALD U. WISE—University of Massachusetts

Consultants:
JAMES G. BECKERLEY—Radioptics, Inc.
CHARLES L. CRITCHFIELD—Los Alamos Scientific Laboratory
EDWARD A. FLINN—Teledyne Co.
NORMAN F. NESS—Goddard Space Flight Center
ROBERT A. PHINNEY [2]—Princeton University

Solar Physics

Chairman:
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Vice Chairman:
GOETZ K. OERTEL—NASA Headquarters

Secretary (Acting):
GOETZ K. OERTEL—NASA Headquarters

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EDWARD L. CHUPP—University of New Hampshire
RICHARD B. DUNN—Sacramento Peak Observatory
EDWARD G. GIBSON—Manned Spacecraft Center
GERHARD B. HELLER—Marshall Space Flight Center
G. RICHARD HUGUENIN—University of Massachusetts
STEPHEN P. MARAN—Goddard Space Flight Center
WILLIAM H. PARKINSON—Harvard College Observatory
PETER A. STURROCK—Stanford University
RICHARD G. TESKE—University of Michigan
RICHARD TOUSEY—Naval Research Laboratory
ORAN R. WHITE—High Altitude Observatory
HAROLD ZIRIN—California Institute of Technology
JACK B. ZIRKER—University of Hawaii

Consultants:
DONALD E. BILLINGS—University of Colorado
WILLIAM G. FASTIE—Johns Hopkins University
HERBERT FRIEDMAN—Naval Rsearch Laboratory
ROBERT J. LIEFELD—New Mexico State University
WILLIAM C. LIVINGSTON—Kitt Peak National Observatory
EDWARD P. NEY—University of Minnesota

[2] Added by this revision.

Space Biology

Chairman:
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Secretary:
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SIDNEY R. GALLER—Smithsonian Institution
SOLON A. GORDON—Argonne National Laboratory
JOHN W. HASTINGS—Harvard University
THOMAS H. JUKES—University of California at Berkeley
NELLO PACE—University of California at Berkeley
COLIN S. PITTENDRIGH—Stanford University
C. LADD PROSSER—University of Illinois
HANS-LUKAS TEUBER—Massachusetts Institute of Technology
CORNELIUS A. TOBIAS—Donner Laboratory

Consultants:
JOHN BILLINGHAM—Ames Research Center
LEON O. JACOBSON—University of Chicago
ALGERNON G. SWAN—Kirtland Air Force Base

Appendix I

NASA's Inventions and Contributions Board

(December 31, 1969)

Chairman	Ernest W. Brackett
Vice Chairman	Leonard Rawicz
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	Clotaire Wood

Appendix J

Patent Waivers Granted and Denied for Separate Inventions Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1–December 31, 1969)

Invention	Petitioner	Action on petition
Polymers and Conductive Compositions Thereof	California Institute of Technology	Granted.
Reflex Depressed Collector	General Electric Co	Do.
Intermediate Frequency Attenuator	California Institute of Technology	Do.
Through Insulation Welding System	do	Do.
Preparation of Stable Colloidal Dispersions in Fluorinated Liquids.	Avco Corp	Do.
Corona Detection Test System	California Institute of Technology	Do.
Primary Absolute Cavity Radiometer	do	Do.
Dicationic Cross-Linking Agents	do	Do.
Non-Toxic Invert Glass Compositions Suitable for High Modulus Glass Fibers.	United Aircraft Corp	Do.
A Novel Polybutadiene	North American Rockwell Corp	Do.
Polyimide Laminate	do	Do.
Stabilization of Polyimidazopyrrolone Compositions	Westinghouse Electric Corp	Do.
Aromatic Heterocyclic Polymers and Stable Precursor Solutions.	do	Do.
Broadband Antennas Having Spiral Windings	General Dynamics Corp	Do.
Multipass Holographic Interferometer	TRW, Inc	Do.
IGFET Strain Transducer Using Piezoelectric Insulator and/or Piezoelectric Substrate.	University of California	Do.
Electrohydrodynamic Generator	Massachusetts Institute of Technology.	Do.
Gas Vortex-Stabilized Radiation Source and Method	Geotel, Inc	Do.
Noncontaminating Swabs	North American Rockwell Corp	Do.
Method for Making Thin Film Superconductors	Westinghouse Electric Corp	Do.
Epoxyorganosilicon Compounds	Monsanto Research Corp	Do.
Development of Processes and Fabrication Techniques to Produce a Monolothic Ferrite Memory Array.	Ampex Corp	Do.
Thermionic Converter with Additives	Thermo Electron Corp	Do.
Optimetric Analysis Sample Holder and Fabrication Method Therefor.	California Institute of Technology	Do.
Integrated Circuit with Multiple Collection Current	Westinghouse Electric Corp	Denied.
Semiconductor Integrated Circuit Having Complementary MIS and Darlington Bipolar Transistor Elements.	do	Do.
Long Range Holographic Contour Mapping	TRW, Inc	Granted.
Systems for Radiant Energy Beam Redistribution	Perkin-Elmer Corp	Do.
Digital Code Generator	Ralph G. Cromleigh	Do.
Control for Maintaining Fuel Cell Electrolyte at Preselected Concentration.	Allis-Chalmers Manufacturing Co	Do.

Appendix K

Patent Waivers Granted and Denied for All Inventions Made during Performance of Contract Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1–December 31, 1969)

Contract description [1]	Petitioner	Action on petition
Gravity Gradient Study	Hughes Aircraft Co.	Granted.
Development of Seal Ring Carbon Graphite Material.	Union Carbide Corp./Carbon Products Division.	Denied.
Flight Instrument for Airborne Collection of Atmospheric Organics.	Atlantic Research Corp.	Granted.
Study for Detecting Failures in a Primary Digital Computer System in Permitting a Secondary Computer System to Assume Control.	IBM Corp.	Do.
Design, Development, Fabrication, Test, and Delivery of a 256 Word Associative Memory.	Honeywell, Inc.	Do.
Development of a Flameproof Organic Fiber	Monsanto Research Corp.	Denied.
Purchase of Flight Qualified Vacuum Gauges for Measuring Ambient Pressure in the Telescope of the Harvard College Observatory ATM Experiment No. ATM S055A.	Norton Research Corp.	Granted.
C–MOS Array Design Techniques	RCA Corp./Defense Electronics Products Division.	Do.
Evaluation of New Materials for Use in Nickel-Cadmium Cells.	Gould, Inc.	Do.
Augmentor Wing Large-Scale Model Tests (Waiver of License Rights).	DeHavilland Aircraft of Canada, Ltd.	Do.
R. & D. of Internal Erasure for Electrochromatic Storage Display Device.	RCA	Do.
Design, Fabricate and Perform Qualification Testing of a Food Warming System for Apollo Spacecraft.	Minnesota Mining & Manufacturing Co.	Do.

[1] Waiver before execution of contract.

Petitions Deferred

Hughes Aircraft Co.
Texas Instruments, Inc.

Appendix L

Scientific and Technical Contributions Recognized by the Agency's Inventions and Contributions Board

(July 1–December 31, 1969)

Awards of $250 or More Granted Under Provisions of Section 306 of the Space Act of 1958, as Amended

Contribution	Inventor(s)	Employer(s)
Automatic Thermal Compensator for Cavity Amplifiers and Filters.	Lloyd J. Derr	Jet Propulsion Laboratory.
Radiant Energy Intensity Measurement System.	Edgar S. Davis	Do.
Detenting Servo Motor	Gerald S. Perkins	Do.
Serial Digital Decoder	Richard R. Green	Do.
Transmission Line Thermal Short	Robert C. Clauss	Do.
Fluid Flow Restrictor	Gilbert J. Bastien	Do.
Broadband Stable Power Multiplier.	George F. Lutes, Jr., Kenneth D. Schreder.	Do.
Space Simulator	James B. Stephens	Do.
Method and Means for Providing an Absolute Power Measurement Capability.	Harold I. Ewen, George G. Haroules, Wilfred E. Brown.	Ewen Knight Corp. and Electronics Research Center.
Protective Camera Enclosure	Richard C. Bailey, William C. Tibbitts.	Jet Propulsion Laboratory.
Noise Limiter	Raymond C. Woodbury	Do.
Two-Axis Fluxgate Magnetometer.	Charles J. Pellerin, Jr., Mario H. Acuna.	Goddard Space Flight Center and Fairchild-Hiller Corp.
Ferrite Cores and Method of Manufacture.	Howard Lessoff	Electronics Research Center.
Voltage to Frequency Converter	Donald C. Lokerson	Goddard Space Flight Center.
Space Suit Audio Transceiver	Herbert E. Cribb	John F. Kennedy Space Center.
Interconnection of Solar Cells	Joseph G. Haynos	Goddard Space Flight Center.
Separation Simulator	Graydon A. Phlieger, Jr	John F. Kennedy Space Center.
Method for Stretching Certain Plastics to Ultra-Thin Films.	Anthony J. Caruso	Electronics Research Center.
Method and Apparatus for Optically Modulating a Light Signal.	William E. Richards, Carl L. Gruber.	Goddard Space Flight Center and University of Maryland.
Energy Limiter for Hydraulic Actuators.	Charles P. Steinmetz	Ames Research Center.
Intumescent Paints	John A. Parker, George M. Fohlen.	Ames Research Center and Applied Space Products Corp.
Dynamic Sensor	John Dimeff	Ames Research Center.
Coulometer and Third Electrode Battery Charging Circuit.	John Paulkovich, Floyd E. Ford.	Goddard Space Flight Center.
Transistor Power Switch	James R. Currie, Frank J. Nola.	George C. Marshall Space Flight Center.

Contribution	Inventor(s)	Employer(s)
Low Power Drain Semi-Conductor Circuit.	Ciro A. Cancro	Goddard Space Flight Center.
Hollow Cylinder Solar Array	Norman Ackerman, Jack Evans, Robert E. Kidwell, William I. Gould.	Do.
Acquisition and Tracking for Optical Radar.	Charles L. Wyman, John M. Gould, Robert E. Johnson, Paul E. Weiss.	George C. Marshall Space Flight Center and Sylvania Electric Products, Inc.
Solid State Switch for an AC Load.	Carl P. Chapman, Donald R. Rupnik.	Jet Propulsion Laboratory.
Vacuum Evaporator with Electromagnetic Ion Steering.	Robert E. Frazer	Do.
Solid State Matrices	Walter A. Hasbach, John V. Goldsmith.	Do.
Cavity Radiometer	Floyd C. Haley	Do.
Electrical Spot Terminal Assembly.	Charles D. Baker	Do.
High-Gain, Broadband Traveling Wave Maser.	Robert C. Clauss	Do.
Apparatus and Method for Separating a Semiconductor Wafer.	Irving Litant, Anthony J. Scapicchio.	Electronics Research Center.
Modified Polyurethane Foams for Fuel-Fire Protection.	John A. Parker, Salvatore R. Riccitiello.	Ames Research Center.
Synchronous DC Direct Drive System.	Leo J. Veillette	Goddard Space Flight Center.
Storage Container for Electronic Devices.	George L. Filip	George C. Marshall Space Flight Center.
An Unsaturating Saturable Core Transformer.	Francis C. Schwarz	Electronics Research Center.
Transistor Servo System	James R. Currie, Frank J. Nola.	George C. Marshall Space Flight Center.
Air Bearing Assembly for Curved Surfaces.	John W. Redmon	Do.
Laser Coolant	John R. Rasquin, Fred R. McDevitt.	George C. Marshall Space Flight Center and Auburn University.
Millimeter-Wave Radiometer for Radio-Astronomy.	Willard V. T. Rusch	Jet Propulsion Laboratory.
High Impact Pressure Regulator	Albert Topits, Jr., Elmer L. Floyd, John E. Biles, Jr.	Do.
Magnetic Core Current Steering Commutator.	Lawrence J. Zottarelli	Do.
Sensing Probe	Lloyd N. Krause, George E. Glawe.	Lewis Research Center.

Space Act Section 306 Awards Summary

(July 1–December 31, 1969)

Types	Number of contributions	Number of awardees	Amount of awards
Space Act awards of $250 or more	45	67	$20,975
Nominal awards of less than $250 to NASA employees	39	50	6,050
$50 minimum awards for filing of patent application	83	137	6,850
$25 minimum awards for publication of NSA *Tech Briefs*	159	257	6,425
Totals	326	511	40,300

Appendix M

EDUCATIONAL BOOKLETS AND FILMS [1]

(July 1–December 31, 1969)

NASA released these new publications and new films during the last half of the year. Other booklets available are described in "NASA Educational Publications" which may be requested from NASA Headquarters, Code FGC–1, Washington, D.C. 20546. Films may be borrowed, without charge except return mailing and insurance costs, from the Media Development Division, Code FAD, or from any NASA Center, and a film list may be obtained by writing to these addresses.

Booklets

Space Resources for Teachers: Space Science.—A curriculum guide for a unified presentation of the natural sciences developed at Columbia University in cooperation with NASA's Goddard Institute of Space Studies. Includes sugestions for classroom activities and laboratory experiments. (EP–64, 144 pp, $2, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

Log of Apollo 11.—A chronology of the first manned landing on the Moon. Illustrated in color. (EP–72, 12 pp, 35 cents, also from the Superintendent of Documents.)

Motion Pictures

Eagle Has Landed: The Flight of Apollo 11 (HQ–194).—Color, 28½ mins., 16 mm. The story of the first landing of men on the

[1] The Agency distributed 2,268,478 publications to teachers, students, professionals, and the public here and abroad, and its film libraries lent 40,014 prints for viewing by an estimated 140 million. Also, the National Audiovisual Center, National Archives and Records Service, sold prints of these films for noncommercial use—including nearly 1,500 of *Eagle Has Landed: The Flight of Apollo 11.* Several were renarrated in foreign languages for worldwide distribution by USIA. NASA's central film depository cataloged and stored 2,208,250 more feet of stock footage (total stored 9,445,930 feet). Nongovernmental producers bought 176,314 feet.

Moon in July 1969. Depicts highlights of the mission from launching through post-recovery activities of the astronauts, emphasizing their exploration of the lunar surface.

Apollo 12: Pinpoint for Science (HQ–197).—Color, 28 mins., 16 mm. A documentary about the second lunar landing mission, concentrating on the accuracy of the landing in the Ocean of Storms and scientific exploration by the astronauts. Features highlights of this November 1969 mission from launch through recovery.

A Mission for Mariner (HQa–191).—Color, 14½ mins., 16 mm. Illustrates (largely through animation) the principal results of an unmanned spacecraft flyby of Venus in 1967, including knowledge gained about the composition and density of the planet's atmosphere, its surface pressure and temperature, mass, and radius.

Within This Decade: America in Space (HQ–191).—Color, 28 mins., 16 mm. Reviews the accomplishments in aeronautical and space research from the establishment of NASA in 1958 until the first lunar landing, with emphasis on the manned space flight program.

Flight Without Wings (HQ–175).—Color, 14½ mins., 16 mm. Traces the development of the wingless "lifting body" aerospacecraft and shows its potential use as a space shuttle to return men to Earth from an orbiting space laboratory. Includes dramatic on-board photography during HL–10 test flights.

Research in the Atmosphere (HQa–180).—Color, 25 mins., 16 mm. A film tracing the methods of man's exploration of the upper atmosphere and near-Earth environment from ancient times to today's sounding rocket and balloon experiments. Shows how study of ionized helium has provided a model for scientific knowledge.

Satellite Astronomy: Progress and Promise (HQ–193).—Color, 17 mins., 16 mm. Reviews the major results of scientific investigations by unmanned satellites during the 1960's and describes briefly possible future exploration of the Sun and planets.

Appendix N

TECHNICAL PUBLICATIONS

(July 1–December 31, 1969)

The following Special Publications, among those issued during the report period by NASA's Scientific and Technical Information Division, are sold by the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, or by the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Va. 22151, at the prices listed.

Conference on Electromagnetic Exploration of the Moon: Report of the Program Evaluation Committee (NASA SP–174).—A summary of contributions that electromagnetic methods might make to lunar exploration. 24 pp. CFSTI $3. August 1969.

Interdisciplinary Approach to Friction and Wear (NASA SP–181).—Edited by P. M. Ku. Lubrication problems concerned with the design and operation of bearings and related devices. 486 pp. GPO $2.25. July 1969.

Surveyor: Program Results (NASA SP–184).—Key findings from five successful Surveyor soft landings on the Moon. 425 pp. GPO $4.75. September 1969.

Average Evoked Potentials: Methods, Results, and Evaluations (NASA SP–191). Emanuel Donchin and Donald B. Lindsley, editors. Problems of the electroencephalogram in the study of the basic mechanisms of neuronal and brain performance as a means of evaluating performance during space flight. 400 pp. GPO $2. December 1969.

Fourth Annual NASA-University Conference on Manual Control (NASA SP–192).—Advances in manual control techniques. 594 pp. CFSTI $3. December 1969.

Evaluation of Motion-Degraded Images (NASA SP–193).—Progress in the development of techniques for the post-facto removal of motion degradations from photographic imagery. 192 pp. GPO $2. August 1969.

Significant Accomplishments in Science: Goddar Space Flight Center, 1968 (NASA SP–195).—Scientific results of the Goddard research program in space sciences. 188 pp. CFSTI $3. August 1969.

NASA Science and Technology Advisory Committee for Manned Space Flight: Proceedings of the Winter Study on Uses of Manned Space Flight, 1975–1985. Volume II: Appendixes (NASA SP–196). —Papers on manned space flight capabilities, low-cost space transportation, the lunar program, astronomy, space physics, earth sciences and applications, life sciences, and materials science and processing in space. 173 pp. CFSTI $3. October 1969.

Atlas of Cometary Forms: Structures Near the Nucleus (NASA SP–198).—By Jürgen Rahe, Bertram Donn, and Karl Wurm. Photographs and photo reproductions of worldwide visual observations of comets between 1835 and 1962. 128 pp. GPO $2.25. December 1969.

Electronic Propulsion Mission Analysis: Terminology and Nomenclature (NASA SP–210).—Results of efforts of a NASA task group to establish a common terminology and nomenclature. 10 pp. CFSTI $3. October 1969.

Future Fields of Control Application (NASA SP–211).—Control theory application to problems in the transportation, biomedical, economic, social, and communication areas. 146 pp. CFSTI $3. October 1969.

Progress of NASA Research on Warm Fog Properties and Modification Concepts (NASA SP–212).—Report on a field experiment in seeding warm fog and laboratory evaluation of several seeding materials. 122 pp. CFSTI $3. October 1969.

A Long-Range Program in Space Astronomy: Position Paper of the Astronomy Missions Board (NASA SP–213).—Robert O. Doyle, editor. A working paper. 305 pp. GPO $1.50. November 1969.

Apollo 11: Preliminary Science Report (NASA SP–214).—Photographs of man's first landing on the Moon, crew observations, accounts of the experiments, and discussions of the lunar samples. 204 pp. CFSTI $3. November 1969.

Compressible Turbulent Boundary Layers (NASA SP–216).—Discussions of compressible turbulent boundary layers and their characteristics. 567 pp. CFSTI $3. November 1969.

Analysis of a Jet in a Subsonic Crosswind (NASA SP–218).—Problems and experimental results of the flow field induced by the efflux of the lifting propulsive device. 249 pp. CFSTI $3. November 1969.

NASA Acoustically Treated Nacelle Program (NASA SP–220).—Proceedings and final results. Interim results were included in NASA SP–189. 165 pp. CFSTI $3. December 1969.

Two-Micron Sky Survey: A Preliminary Catalog (NASA SP–3047).—G. Neugebauer and R. B. Leighton, editors (CIT). Lists all objects detected in a survey to obtain an unbiased sample of celestial objects that emit in the infrared region. 322 pp. CFSTI $3. June 1969.

Computer-Aided Filter Design Manual (NASA SP–3049).—By Sidney Gussow and Glenn Weathers. Procedures that give experienced or inexperienced filter designers a comprehensive filter design capability. 101 pp. GPO $1.25. September 1969.

Tabulations of Configuration Factors Between Any Two Spheres and Their Parts (NASA SP–3050).—By Norman T. Grier. Tables of values of the configuration factors between two spheres, between parts of one sphere and parts of another sphere, and between a point on one sphere and parts of another sphere. 420 pp. CFSTI $3. September 1969.

Semiclassical Elastic Scattering Cross Sections for a Central Field Potential Function (NASA SP–3052).—By James R. Stallcop. Outlines the development and application of the semiclassical scattering approximation to the partial wave description. Includes formulas and tables. 296 pp. CFSTI $3. December 1969.

Project Gemini Technology and Operations: A Chronology (NASA SP–4002).—By James M. Grimwood and Barton C. Hacker with Peter J. Vorzimmer. Listing of major events and managerial decisions in the two-manned space flight program. 308 pp. GPO $2.75. July 1969.

The Apollo Spacecraft: A Chronology. Volume I: Through November 7, 1962 (NASA SP–4009).—By Ivan D. Ertel and Mary Louise Morse. Chronology on the development of the Apollo spacecraft and lunar mission; lists important events that have affected the concept, design, and development of the spacecraft. 269 pp. GPO $2.50. July 1969.

Index to NASA Tech Briefs, January—June 1969 (NASA SP–5021(09)).—Lists of technological innovations published as *Tech Briefs*. 53 pp. CFSTI $3. September 1969.

Clean Room Technology (NASA SP-5074).—By James W. Useller. Publication of lectures used to train technicians and their supervisors on the characteristics and operation of a clean room. 65 pp. GPO 35 cents. August 1969.

Aerospace Related Technology for Industry (NASA SP-5075). Proceedings of a conference on technology sources and services. 183 pp. CFSTI $3. July 1969.

Contamination Control Handbook (NASA SP-5076). Contamination control in product design, gases and liquids, radiation, as well as control of airborne and microbial contamination. 385 pp. CFSTI $3. November 1969.

Management: A Continuing Literature Survey With Indexes NASA SP-7500(03).—Selected references to unclassified reports and journal articles entering the NASA Information System in 1968. 51 pp. CFSTI $3. August 1969.

The Systems Approach to Management: An Annotated Bibliography With Indexes (NASA SP-7501).—The systems approach to management and its impact across a broad spectrum of business and Government activity. 62 pp. CFSTI $3. August 1969.

Meteoroid Environment Model—1969 (*Near Earth to Lunar Surface*) (NASA SP-8013).—The meteoroid environment of cometary origin in the mass range between 10^{-12} and 1 AU from the sun near the ecliptic plane. 31 pp. CFSTI $3. October 1969.

Effects of Structural Flexibility on Spacecraft Control Systems (NASA SP-8016).—Discusses the selection, design, and evaluation of a spacecraft control system in the presence of a flexible structure. 43 pp. CFSTI $3. September 1969.

Magnetic Fields—Earth and Extraterrestrial (NASA SP-8017).—Information on natural magnetic fields applicable in the design of space vehicles, onboard equipment, and instrumentation. 65 pp. CFSTI $3. October 1969.

Spacecraft Magnetic Torques (NASA SP-8018).—Discusses the magnetic torque resulting from the interaction between the magnetic properties of the spacecraft and the ambient magnetic field. 51 pp. CFSTI $3. July 1969.

Mars Surface Models (*1968*) (NASA SP-8020).—A set of engineering models of the Mars surface and of the mechanical, electrical, and thermal properties required for vehicle design. 69 pp. CFSTI $3. December 1969.

Models of Earth's Atmosphere (120 to 1000 km.) (NASA SP–8021).—A computerized version of Jacchia's prediction method to provide models of the earth's atmosphere. 37 pp. CFSTI \$3. December 1969.

Lunar Surface Models (NASA SP–8023).—Models based on 1968 state-of-the-art upgrade and extend earlier engineering models. 55 pp. CFSTI \$3. December 1969.

Aerodynamic and Rocket-Exhaust Heating During Launch and Ascent (NASA SP–8029).—Monograph. 29 pp. CFSTI \$3. Feb. 1970.

Appendix O

Major NASA Launches

(July 1–December 31, 1969)

Name, date launched, mission	Vehicle	Site [1]	Results
Apollo 11 (AS–506), July 16. To land men on the moon and return them safely to earth.	Saturn V	ETR	Astronauts Armstrong and Aldrin touched down on the lunar surface on July 20 while Astronaut Collins orbited the moon. The two astronauts obtained samples of the lunar soil, photographed the surface, and set up scientific experiments. The crew was recovered from the Pacific Ocean at 1:57 p.m., e.d.t., July 24.
OSO–6 (OSO–G), August 9. Orbiting solar observatory designed to obtain high spectral resolution data from onboard experiments pointed toward the Sun.	Delta	ETR	The spin-stabilized spacecraft was successfully launched into a 350-mile circular orbit above the Earth. Its experiments were providing data as planned.
ATS–5 (ATS–E), August 12. An Applications Technology Satellite to conduct a gravity gradient orientation experiment to help provide basic design data for stabilization and control of long-lived spacecrafft in synchronous orbit.	Atlas-Centaur.	ETR	Launched into a synchronous 22,300-mile orbit. Spacecraft malfunctioned shortly after launch, but over half of its experiments were providing useful information.
Pioneer E, August 27. Tenth (and last) in the first series of Pioneer spacecraft—to orbit the Sun, investigating the interplanetary medium and solar activity and their influence on Earth's environment.	Delta	ETR	Spacecraft lost during launch when the Delta vehicle malfunctioned.

[1] See footnote at end of table.

Major NASA Launches Cont'd

(July 1–December 31, 1969)

Name, date launched, mission	Vehicle	Site [1]	Results
Apollo 12 (AS-507), November 14. To develop techniques for a point landing capability; perform selenological inspection, survey, and sampling in a mare area; deploy and activate the ALSEP; develop man's capability to work in the lunar environment; and photograph candidate exploration sites.	Saturn V	ETR	Astronauts Conrad and Bean landed the lunar module about 600 feet from their target—Surveyor 3—on November 19; Gordon remained in the command module orbiting the moon. Except for loss of TV coverage on the lunar surface (probably due to direct exposure of the camera lens to sunlight), the mission proceeded as planned. EVA's were as scheduled, and lift off occurred without difficulty at 9:26 a.m., e.s.t., November 20. The crew was recovered from the Pacific at 4:58 p.m., e.s.t., November 24.

Non-NASA Missions

Name, date launched, mission	Vehicle	Site [1]	Results
INTELSAT 3 F-5, July 26. Global telecommunications satellite launched by NASA for Comsat (on a reimbursable basis) to form part of a commercial communications satellite network.	Delta	ETR	Launch vehicle malfunction kept the satellite from achieving a proper transfer orbit.
ESRO-1B, October 1. Satellite launched by NASA (on a reimbursable basis) for the European Space Research Organization for studying the polar ionosphere, Northern Lights, and related phenomena.	Scout	WTR	The spacecraft was successfully placed into a near-polar orbit (apogee 270; perigee 248 miles). Its experiments were operating as planned.
AZUR-1, November 7. First cooperative satellite with West Germany. To transmit data on Earth's radiation belts.	Scout	WTR	Research satellite placed into nearly polar elliptical orbit reaching altitude of 1,600 miles. Its eight instruments—developed in German laboratories—were measuring magnetic fields, protons, electrons, and ultraviolet radiation.
Skynet-A, November 22. Communications satellite.	Delta	ETR	Launched by NASA for the United Kingdom. All systems were operating as planned.

[1] ETR—Eastern Test Range, Cape Kennedy, Fla.
WTR—Western Test Range, Point Arguello, Calif.

Appendix P

NASA Launch Vehicles

Payload in pounds

Vehicle	Stages	345-mile orbit	Escape	Mars/ Venus	Principal use
Scout	4	310	----------	----------	Launching small scientific satellites, reentry experiments and probes (Explorers 37, 39, and 40, Reentry F, Radio Attenuation Measurement-C, and ESRO 1A and 2B).
Thrust Augmented Delta (TAD).	3	2,000	525	500	Launching scientific, meteorological, communications, and Biosatellites A–F, and lunar and planetary probes (Pioneer 6, TIROS M, TIROS operational satellites OT–3 and –2, Syncom 3, Commercial Communications Satellite Early Bird 1, Radioastronomy Explorer, INTELSAT 1, 2, and 3 communications satellites, and International Satellites for Ionospheric Studies—ISIS).
Thrust Augmented Thor-Agena (TAT).	2	2,600	----------	----------	Launching geophysics, astronomy and applications satellites (OGO C, D, and F, Nimbus B2 and D, and SERT 2).
Atlas-Centaur	2½	9,900	2,600	1,600	Launching medium weight unmanned spacecraft (Mariner, ATS, OAO, and Pioneer, and INTELSAT 4).
Saturn IB	2	[1] 40,000	----------	----------	Launching Apollo CSM for SL–2, SL–3 and SL–4 missions.
Saturn V	3	[1] 300,000	106,000	------	Launching Apollo spacecraft for lunar missions.

[1] For 100-nautical-mile orbit.

Appendix Q

Institutions Currently Participating in NASA Predoctoral Training Program

(July 1–December 31, 1969)

Adelphi University
Alabama, University of
Alaska, University of
Alfred University
Arizona State University
Arizona, University of
Arkansas, University of
Auburn University
Baylor University
Boston College
Boston University
Brandeis University
Brigham Young University
Brooklyn, Polytechnic Institute of
Brown University
California Institute of Technology
California, University of, at Berkeley
California, University of, at Los Angeles
California, University of, at Riverside
California, University of, at San Diego
California, University of, at Santa Barbara
Carnegie-Mellon University
Case Western Reserve University
Catholic University of America
Chicago, University of
Cincinnati, University of
Clark University
Clarkson College of Technology
Clemson University
Colorado School of Mines
Colorado State University
Colorado, University of
Columbia University
Connecticut, University of
Cornell University [1]
Dartmouth College
Delaware, University of
Denver, University of
Drexel Institute of Technology
Duke University
Duquesne University
Emory University
Florida State University
Florida, University of
Fordham University
George Washington University
Georgetown University
Georgia Institute of Technology [1]
Georgia, University of
Hawaii, University of
Houston, University of
Howard University
Idaho, University of
Illinois Institute of Technology
Illinois, University of
Indiana University
Iowa State University
Iowa, University of
Johns Hopkins University
Kansas State University
Kansas, University of [1]
Kent State University
Kentucky, University of
Lehigh University
Louisiana State University
Louisville, University of
Lowell Technological Institute
Maine, University of
Marquette University
Maryland, University of
Massachusetts Institute of Technology
Massachusetts, University of
Miami, University of [5]
Michigan State University
Michigan Technological University
Michigan, University of
Minnesota, University of
Mississippi State University
Mississippi, University of
Missouri, University of
Missouri, University of, at Rolla
Montana State University
Montana, University of
Nebraska, University of
Nevada, University of
New Hampshire, University of
New Mexico State University
New Mexico, University of
New York, The City University of
New York, State University of, at Buffalo

See footnotes at end of table.

New York, State University of,
at Stony Brook
New York University
North Carolina State
of the University of North Carolina[4]
North Carolina, University of
North Dakota State University
North Dakota, University of
Northeastern University
Northwestern University
Notre Dame, University of
Ohio State University
Ohio University
Oklahoma State University
Oklahoma, University of
Oregon State University
Pennsylvania State University[4]
Pennsylvania, University of
Pittsburgh, University of[2]
Princeton University
Purdue University[1]
Rensselaer Polytechnic Institute
Rhode Island, University of
Rice University
Rochester, University of
Rutgers—The State University
St. Louis University
South Carolina, University of
South Dakota, University of
Southern California, University of[2,6]
Southern Illinois University
Southern Methodist University
Southern Mississippi, University of
Stanford University[1,3]
Stevens Institute of Technology
Syracuse University
Temple University
Tennessee, University of
Texas A&M University
Texas Christian University
Texas Technological College
Texas, University of
Toledo, University of
Tufts University
Tulane University
Utah State University
Utah, University of
Vanderbilt University
Vermont, University of
Villanova University
Virginia Polytechnic Institute
Virginia, University of
Washington State University
Washington University (St. Louis)
Washington, University of
Wayne State University
West Virginia University
William and Mary, College of
Wisconsin, University of
Worcester Polytechnic Institute
Wyoming, University of
Yale University
Yeshiva University

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[1] Institutions receiving training grants specifically for engineering systems design.
[2] Institutions receiving training grants specifically for administration and management.
[3] Institutions receiving training grants specifically for laser technology, and aeronautics.
[4] Institutions receiving training grants specifically for vibrations and noise.
[5] Institutions receiving training grants specifically for international studies in science and technology.
[6] Institutions receiving training grants specifically for communications science.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1970 O—400-542